2014

Untangling compact and diffuse ionized emission toward galactic hii regions

Logan A. Hough
West Virginia University

Follow this and additional works at: <https://researchrepository.wvu.edu/etd>

Recommended Citation

Hough, Logan A., "Untangling compact and diffuse ionized emission toward galactic hii regions" (2014). *Graduate Theses, Dissertations, and Problem Reports*. 226.
<https://researchrepository.wvu.edu/etd/226>

This Thesis is protected by copyright and/or related rights. It has been brought to you by the The Research Repository @ WVU with permission from the rights-holder(s). You are free to use this Thesis in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you must obtain permission from the rights-holder(s) directly, unless additional rights are indicated by a Creative Commons license in the record and/ or on the work itself. This Thesis has been accepted for inclusion in WVU Graduate Theses, Dissertations, and Problem Reports collection by an authorized administrator of The Research Repository @ WVU. For more information, please contact researchrepository@mail.wvu.edu.

Untangling Compact and Diffuse Ionized Emission toward Galactic H II Regions

Logan A. Hough

Dissertation submitted to the
Eberly College of Arts and Sciences
at West Virginia University
in partial fulfillment of the requirements
for the degree of

Master of Science
in
Physics

Dr. Loren Anderson, Ph.D., Chair
Dr. Duncan Lorimer, Ph.D.
Dr. D.J. Pisano, Ph.D.

Department of Physics and Astronomy

Morgantown, West Virginia
2013

Keywords: H II Region, Radio Recombination Line
Copyright 2013 Logan A. Hough

ABSTRACT

Untangling Compact and Diffuse Ionized Emission toward Galactic H II Regions

Logan A. Hough

H II regions are clouds of ionized hydrogen gas surrounding B0- and O-type stars. The ionized hydrogen in these regions emits both radio recombination line (RRL) and also thermal radio continuum. Diffuse ionized hydrogen, known as the 'Warm Ionized Medium' (WIM) also exists in the Galaxy. The WIM also emits RRLs and thermal radio continuum. Previous observation of compact H II regions found two RRL components for many sources, one from the H II region and the others from the WIM. By observing off-target positions sampling only the diffuse emission, we discerned the correct source velocities for 93 out of 116 H II regions that have multiple RRL components. We assigned kinematic distances to these sources by analyzing hydrogen absorption spectra taken toward the sources. We found that 64% of our sources lie beyond the tangent point distance.

Dedication

The author wishes to dedicate this thesis to
Cheryl and Andrew Hough.

Acknowledgments

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

I would like to give special thanks to Dr. Loren Anderson for guidance while completing this thesis and to the members of my Review Committee.

Table of Contents

List of Figures	viii
1 Introduction	1
2 Observations and Data Reduction	7
2.1 Sources	8
2.2 Data Reduction	9
3 Analysis	10
4 Results	18
5 Summary	25
6 Tables and Comments on Individual Sources	27
6.1 Tables	27
6.2 Comments on Individual Sources	45

List of Tables

6.1 H II Region Line Parameters	26
6.2 Line Parameters of Diffuse Emission	28
6.3 H II Region Velocities and Distances	40

List of Figures

3.1	Radio continuum map and Radio spectra	12
3.2	KDA diagram	16
4.1	Longitude-velocity diagram	21
4.2	Longitude-distance diagram	23

Chapter 1

Introduction

Stars have a wide range of masses. In solar mass units, $M_{\odot}$, stellar masses range from about $0.1 M_{\odot}$ to $100 M_{\odot}$. Massive stars are quite rare compared to the stellar population as a whole. High mass stars are short lived, using up their hydrogen quickly compared a lower mass stars. With their high temperatures, these massive stars are very bright in the visual and ultraviolet bands of the electromagnetic spectrum. Assuming these stars are approximately blackbody radiators, the peak radiation shifts to ultraviolet frequencies. Stars with masses greater than $\sim 10 M_{\odot}$ are classified as B0- and O-type in the stellar spectral classification system.

Hydrogen is the most abundant element in the universe.

Unsurprisingly, hydrogen is found surrounding massive stars. A hydrogen atom consists of a nucleus accompanied by an orbiting electron. A hydrogen ion is a charged particle, more specifically a proton, created when a photon with an energy of at least 13.6eV ionizes a hydrogen atom.

Hydrogen surrounding stars that are less luminous than B0-type is not

ionized in appreciable amounts. The electromagnetic emission of these stars is not of a high enough frequency to ionize hydrogen. H II regions are areas of ionized hydrogen surrounding massive stars.

When a region of hydrogen is ionized a process called recombination occurs. Recombination is the process of the electrons that were split from the hydrogen atoms colliding with hydrogen ions and becoming associated again; a 'new' hydrogen atom is formed. Electrons that recombine into an excited state will cascade down the energy levels of the atom toward the ground state, emitting photons with specific energies that may be observed with radio telescopes, among other instruments.

Since recombination lines can be observed at many different frequencies (and therefore energies), it takes a large number of different instruments to observe them at the different bands of the electromagnetic spectrum. Visual band recombination lines are attenuated by dust and therefore observations must be taken at lower frequencies. In the radio regime, you may observe sources in the outer parts of the Galaxy because the signal does not scatter and absorb as much as it would at high frequencies. Large arrays of radio telescopes as well as massive single dish telescopes may be constructed. These radio telescopes are quite sensitive;

with their large signal collection area, very faint sources may be studied.

Recombination line emission occurs over a wide range of wavelengths, from the Lyman α ($2 \rightarrow 1$) recombination line in the ultraviolet band to Recombination lines above the ($41 \rightarrow 40$) line in the radio portion of the electromagnetic spectrum (Lilley & Palmer, 1968). The frequency of the emitted photon corresponds to the electrons energy level according to:

$$\nu_0 = R_M c \left(\frac{1}{n^2} - \frac{1}{(n + \Delta n)^2} \right) \quad (1.1)$$

Here n corresponds to the final energy level, Δn the change in energy levels, and R_M is a generalization of the Rydberg constant that accounts for the finite mass of atomic nuclei. Adjacent recombination lines (i.e. H 100 α and H 101 α , the 100th and 101st α recombination lines of hydrogen) are of similar intensity. This allows one to average lines together, providing the opportunity to observe weak sources.

Each H II region also has a thermal radio continuum (Bremsstrahlung radiation), as well as additional continuum emission when the electrons first recombine (free-bound emission). Bremsstrahlung radiation is produced when negatively charged electrons are accelerated by positively charged protons. Observing the former emission provides you with the continuum

spectrum. This continuum spectrum may be used in conjunction with radio recombination line observations to determine the physical properties of H II regions.

H II regions themselves come in many shapes and sizes. There are individual, isolated H II regions, some maybe even powered by single stars. For example, at a distance of 1.35 kpc, the star powering RCW 120 has been found to be a single O7 star (Martins et al., 2010). This is not the norm however; large complexes of H II regions are observed, especially in the crowded inner galaxy.

It is possible to observe some structures originating from H II regions. Among these structures are plumes of the ionized hydrogen known as worms, blown out of the Galactic plane by pressures within the H II region and by supernovae. An excellent example of some of these properties is the massive H II region W43. Composed of many individually identified regions and collectively powered by many giant O-type stars, W43 has two massive worms; one both above and below W43 itself, which lies roughly within the Galactic plane (Heiles et al., 1996).

Some photons produced by H II regions leak into the interstellar medium, ionizing hydrogen present there. These electrons are known from

observations of pulsars. When a pulsar emits a pulse, that signal must travel through the interstellar plasma that lies between the source and the Earth. Because the electromagnetic signal does not travel in a vacuum, the arrival time's be delayed. This delay is related to a factor known as dispersion measure, DM. Dispersion measure is the integral of the free electron density along the path between Earth and the source. The interstellar medium also affects the polarization of a signal. Similar to DM, rotation measure (RM) accounts for the change in the polarization angle of a signal due to magnetic fields. These media are not isotropic though and there is a different dispersion measure for each direction in the Galaxy.

The warm ionized medium (WIM) is a major component of the interstellar medium of the Galaxy. The WIM emits in both recombination line and continuum emission. It has a temperature of $\sim 10^4\text{K}$ and is nearly completely ionized. This may lead to complications when interpreting observations of H II regions. If the WIM has strong emission at a position coincident with an H II region, multiple velocity components will be detected. It may be difficult to identify the correct H II region source velocity.

The H II Region Discover Survey (HRDS) was conducted with the

Green Bank Telescope. There were 603 radio recombination line (RRL) components detected from 448 sources that ranged from longitudes of 343° to 67° . The HRDS detected two or more RRL components toward 129 sources (Anderson et al., 2011). In Anderson et al. (2011), for each source, all components except one are assumed to originate from the WIM. The detection of these diffuse components was possible due to the excellent sensitivity of the HRDS.

Chapter 2

Observations and Data Reduction

Our observations were made with the GBT 100 m telescope from 2012 August through 2013 April. Using the X-band receiver (9 GHz), we followed the observational procedures of Anderson et al. (2011). The GBT beam at X-band is $82''$. Each observation was a total power, position switched pair. We first obtain pointing and focus corrections by observing a source of known position and intensity. No corrections for atmospheric effects were made. The data were reduced with TMBIDL software (T. M. Bania, 2014, private communication).

We simultaneously observe the $H\,87\alpha$ to $H\,93\alpha$ transitions. These transitions can be averaged together to improve the RRL signal-to-noise ratio, thus giving a more sensitive ($H\,n\alpha$) composite spectrum (Balser, 2006). The spectra were taken in position switching mode with on- and off-source integrations of 6 minutes each. The off-source position observation followed the same path on the sky as the on-source position.

2.1 Sources

We had two subsets of sources; multiple-velocity HRDS sources and multiple-velocity H II regions from the literature. Our sources ranged from longitudes of 17° to 50° . Of our 125 observed sources, 29 were from the literature (Lockman, 1989; Lockman et al., 1996; Sewilo et al., 2004), the rest from HRDS. The observing procedure was different for the two sets of sources. We observed the on-source position for the sources from the literature, but not the one from the HRDS. This was to confirm the sources had two velocity components and to get accurate X-band lines intensities. (Lockman, 1989; Lockman et al., 1996; Sewilo et al., 2004).

We chose off-target positions at least one beam width away from the extent of the multiple-velocity source and any other nearby sources. Our hypothesis was that we would detect only diffuse emission at this off-target position. If the results were inconclusive, we picked a different off-target position. The new position was usually on the opposite side of the source with respect to the original position, still being careful to avoid any compact sources of radio emission. In some cases, a third, or even fourth, off-target position was needed.

2.2 Data Reduction

We smooth the ($\text{H n } \alpha$) spectrum to a velocity resolution (1.86 km s^{-1}) that compares favorably with the FWHM recombination line widths (25 km s^{-1}) (Anderson et al., 2011). After the spectrum is smoothed we remove a baseline and fit a Gaussian to each velocity component that was detected. Through this procedure we derive the LSR velocity, line intensity, and FWHM for each component.

Chapter 3

Analysis

Given a spectrum with multiple velocity components, we assume that one component is from a compact H II region while the others are from diffuse ionized gas. The goal of this analysis is to correctly identify the source velocity of H II regions with multiple velocity components. If we observe a position near the source (off-target position), the only emission that should be detected is that of the diffuse components.

We associate a velocity component from a source spectrum with a component from an off-target spectrum if their velocities are within 10 km s^{-1} of each other. A 10 km s^{-1} difference of velocity components in the first quadrant of the Galaxy leads to differences in kinematic distances of $\simeq 1 \text{ kpc}$. For example, a 30 km s^{-1} component versus 40 km s^{-1} component at $(\ell, b) = (30^\circ, 0^\circ)$ has a 0.59 kpc discrepancy. Sometimes two components were detected in an off-target spectrum whereas one was detected in the on-target spectrum (or vice-versa). We associate multiple components in an off-target spectrum with a single component in an

on-target spectrum (or vice-versa) if the off-target spectrum components are each within 10 km s^{-1} of the on-target spectrum component.

We developed a set of criteria that we applied to our sources when determining the correct source velocity. Below we describe our nine criteria in order of decreasing confidence. These criteria are not necessarily mutually exclusive. 1: The clearest scenario is one where one line not detected in the off-target position spectrum was detected in the source-position spectrum. The velocity component that is not detected at the off-target position is the velocity of the H II region (Figure 3.1). 2: A more complicated situation was if the RRL intensity of all lines detected in the source spectrum was non-zero in the off-target spectrum. In this case, if the intensity of one line decreases to 50% of its intensity from the source spectrum, while each other line did not decrease this requisite amount, that the velocity of the line that decreased in intensity by 50% was that of the H II region.

3: The next criterion deals with velocity components that were detected at the off-target position but were not detected with intensities at least 50% weaker than those of the source observation. The most intense line of diffuse emission that we detected was 50 mK. If the intensity of a

Figure 3.1: Radio continuum map and Radio spectra. Data for G30.249+0.243 (top row) and G25.305+0.532 (bottom row). The images show emission from *Spitzer* GLIMPSE 3.6 μm (blue), GLIMPSE 8.0 μm (green), and MIPS GAL 24 μm (red). VGPS 21 cm continuum contours are overplotted in white and the GBT beam at X-band is in the lower left of each image. The black crosses show the original HRDS positions and the red crosses show the off-target positions. (The infrared source nearly coincident with the red cross for G30.249+0.243 has no associated radio continuum and therefore did not affect these observations). The spectra show off-target data (red cross locations). The red curves in the spectra are Gaussian fits to the line components found in the HRDS (black cross locations). In both cases, only one velocity component is detected and its line strength and velocity are similar to one of the components detected previously. The situation is therefore unambiguous: in the off-target observations we detected the diffuse component and the source velocities are 8.9 km s^{-1} and 7.0 km s^{-1} , respectively.

RRL of any source decreased by more than this amount, it was determined to be the source velocity.

4: Of all the sources not observed in the HRDS (that were all reported to have multiple velocities), we detected five with only one velocity component; this was assumed to be the correct source velocity. 5: Some HRDS sources had a velocity component with a negative value. In the first Galactic quadrant a source with a negative velocity can only be beyond the orbit of the Sun. These negative velocity sources are rare in this first quadrant and diffuse negative velocity emission is very unlikely. Therefore, if one component is at a negative velocity, this is likely the correct source velocity.

We had continuum data for the HRDS sources that allowed us to analyze the relationship between the continuum intensity and RRL intensity. 6: Quireza et al. (2006) found the average ratio of RRL intensity to continuum intensity (T_L/T_C) at X-band is 9.18%. For their sample, a 1σ deviation from this value ranges from 6.85% to 11.50%. If the intensity ratio of one of the velocity components of a source spectrum was within this range, and the ratio of all other components was outside of the range, the velocity inside of the range was the source velocity. 7: Similarly, a 3σ deviation from the average is less than 2.20% and greater than 16.15%. If the intensity ratio of all but one velocity component of the source spectra

lies outside of this 3σ deviation, the one component within this range is the source velocity.

The H II regions that we observed have been observed with other tracers besides ionized hydrogen. H II regions have associated cool, dense, molecular clouds. We compared RRL velocities from these molecular tracers to the HRDS sources and multiple-velocity sources from the literature. 8: If there was a molecular line observation that had a common velocity measurement with only one of our detected velocity components (within 10 km s^{-1}), we determined that the aforementioned velocity was the source velocity. We did a more specific comparison for the sources we observed that were not observed with the HRDS. Anderson et al. (2009) developed qualitative criteria for the quality of association between an H II region and ^{13}CO from the Galactic Ring Survey (Jackson et al., 2006). 9. Using the A and B rated sources (ones in which the molecular gas is coincident, or only slightly offset, in position and velocity with the radio continuum), if only one of these CO velocities were within 10 km s^{-1} of one of our velocity components we determined that was the source velocity. If an A or B rated source showed compact CO emission at multiple velocities, no association was made.

Sources in the Milky Way rotate about the center of the Galaxy and we model this with rotation curves. There is a kinematic distance ambiguity (KDA) when trying to find the distance to sources inside the orbit of the Sun. In the first quadrant of our Galaxy, a positive radial velocity has two corresponding distances, known as the near and far distance. As shown in Figure 3.2, these distances are evenly spaced around a tangent point distance that has maximum radial velocity at any given Galactic longitude. As mentioned before, a negative velocity unambiguously indicates a singular distance outside of the orbit of the Sun.

Analysis of neutral hydrogen absorption allows for the kinematic distances to the sources to be determined. This analysis is the same as in the works of Anderson & Bania (2009) and Anderson et al. (2012). To resolve the kinematic distance ambiguity we look for absorption of continuum emission by foreground, neutral hydrogen. The absorption spectra we use for this analysis were created using data from VGPS (Stil, 2006). For each H II region, an on-source spectrum was subtracted from an off-source spectrum to clearly identify any absorption. The off-source spectrum was taken at a position as close to the source as possible so we can sample the same HI column.

Figure 3.2: KDA diagram. This diagram represents a source that is observed at a velocity of 40 km s^{-1} at $(\ell, v) = (30, 0)$. At this velocity and position, the near distance is 2.78 kpc while the far distance is 11.95 kpc . These lie around the tangent point with a velocity of 107.4 km s^{-1} , corresponding to a distance of 7.36 kpc .

If absorption only occurs up to the source velocity, the source is at the near distance. If a source velocity is within 10 km s^{-1} of the tangent point velocity, we assign the tangent point distance. This 10 km s^{-1} window around the tangent point accounts for streaming motions within the

Galaxy's spiral arms that deviate from the rotation curve model we use to compute our distances. If absorption occurs between the source and the tangent point velocity, the source is at the far distance. For each source we assign a quality factor based on how sure we were of the determination.

Chapter 4

Results

We observed on- and off-target positions for the 29 sources that were not observed in the HRDS. From the set of 29 sources, we found that there are five with one velocity component, 22 with two velocity components, and two with three velocity components. The position, line height, velocity, FWHM, and RMS noise for each velocity component of non-HRDS sources are listed in Table 6.1. We do no more analysis with the five single-velocity sources; they are probably spurious detections from the literature.

Listed in Table 6.2 are all of the components from off-target positions. The same parameters as those in Table 6.1 are included in this second table, as well as the separation between the source and off-target position. We sometimes used a single off-target position for multiple source velocity determinations if the sources were near each other in the sky; this is indicated in the table.

We determined the source velocity for 93 of 116 sources. Twenty-four of those sources have one line not detected in the off-target position spectra

that was detected in the source-position spectra (criterion 1). Thirty-one sources have one component that decreases to 50% of its intensity from the source spectra, while each other line did not decrease this requisite amount (criterion 2). Nine sources have the intensity of a component decrease by 50 mK, which is a higher intensity than the most intense line of diffuse emission that we detected (criterion 3). Eight sources have only one component with an RRL intensity to continuum intensity (T_L/T_C) ratio within one-sigma deviation of the average in Quireza et al. (2006), 9.18% at X-band (criterion 6). Thirty-one sources have all but one component outside of a three-sigma deviation from the average (criterion 7). Seven sources have a CO observation cospatial with the source position (criterion 9) and 23 have another associated, dense gas tracer (criterion 8). Four non-HRDS sources have a single component with a positive velocity (criterion 4) and one non-HRDS source has a single component with a negative velocity (criterion 5).

We resolve the KDA of the sources for which we determine the source velocities. Not including the sources that we determined were at the tangent point distance, we were able to resolve the KDA for 76 of the 93 H II regions (82%). Listed in Table 6.3 are our determined source velocities,

the near and far distance of the KDA for a source’s position, our determination of which is the correct distance, a quality factor of our determination, the Galactic radius, the distance from Earth, the distance above or below the Galactic plane, and the reasons for our distance determination for each source.

Twenty-seven sources are at the near distance. We assigned 11 of these sources an A quality factor and 16 of them a B. At the far distances there are 49 sources; 22 with an A quality factor and 27 with a B. The higher number of sources at the far distance (64%) is in agreement with Anderson et al. (2012) which found a majority (61%) of the HRDS sources lie at the far distance.

Figure 4.1 is a Galactic Longitude–Velocity diagram that includes all of our source and diffuse components with a positive velocities, between Galactic Longitudes 17° and 39° . The background is ^{13}CO emission from the Galactic Ring Survey, integrated over $|b| \leq 1^\circ$. The size of each circle is related to the intensity of the component. Source components are plotted in red, while the diffuse components are plotted in green.

The emission we detect from the diffuse H II gas is correlated in (ℓ, v) with ^{13}CO . Most of the sources in the $30\text{--}60\text{ km s}^{-1}$ velocity range are at

Figure 4.1: Longitude-velocity diagram. Our data are overlaid on an image of ^{13}CO emission, integrated over latitude, from the Galactic Ring Survey. The circle sizes correspond to the intensity of each RRL component. There is good correlation between the RRL emission and that of the ^{13}CO . A large portion of the diffuse H II emission is located around the tangent point velocity (or distance). Also apparent are higher concentrations of emission around 24° and 31° longitude. The emission at 31° is associated with the H II region W43.

the far distance of the KDA, around 11–12 kpc from the Galaxy’s center.

It is hard to detect the faint ^{13}CO signal at these far distances so it is

reasonable that our observations do not match as well around these

velocities. Our most intense emission occurs around 24° and near the H II

region W43 at 31° .

The velocity range of $30\text{--}60\text{ km s}^{-1}$ contains 35 of our source components and 105 of our diffuse components. The velocity range of $80\text{--}120\text{ km s}^{-1}$ contains 45 of our source components and 202 of our diffuse components. The two velocity ranges have similar ratios of number of source components to diffuse components, 33% for $30\text{--}60\text{ km s}^{-1}$ and 22% for $80\text{--}120\text{ km s}^{-1}$.

The average intensity ($\pm$ one standard deviation) of the source components at $30\text{--}60\text{ km s}^{-1}$ was $50.4\pm43.8\text{ mK}$. For the $80\text{--}120\text{ km s}^{-1}$ velocity range, this value was $71.0\pm76.1\text{ mK}$. The average intensity of the diffuse components was $12.5\pm10.2\text{ mK}$ and $16.9\pm11.3\text{ mK}$ for the velocity ranges $30\text{--}60\text{ km s}^{-1}$ and $80\text{--}120\text{ km s}^{-1}$, respectively.

Figure 4.2 is a Galactic Longitude–Distance diagram that includes our source positions with known distances, marked by the red circles. The size of the red circles is related to the intensity of the component. Also plotted are black circles at the positions of ^{13}CO clouds (Roman-Duval et al., 2009). The size of the circles corresponds to the masses of these clouds; the masses were separated into 4 bins for better clarity. The four mass bins are less than $10^5 M_\odot$, between 10^5 and $2.5\times10^5 M_\odot$, between

Figure 4.2: Longitude-distance diagram. The red circles are our source positions and the black circles are ^{13}CO gas cloud positions. The red circle sizes relate to the intensity of the component while the four black circle sizes correspond to binned masses of the gas clouds. RRL velocities associated with each distance are shown along the top axis, visualizing the Kinematic Distance Ambiguity. There are a larger number of sources at the tangent and far distances. Though numerous, the ^{13}CO clouds do seem to correlate to our data, especially the higher mass clouds.

2.5×10^5 and $5 \times 10^5 M_{\odot}$, and more than $5 \times 10^5 M_{\odot}$. Plotted along the top of the figure are the velocities associated with the distance from the Sun. The KDA is illustrated clearly here and we observe 29% of our sources at the near distance, 18% at the tangent, and 53% at the far. Velocities from

80–120 km s^{-1} are highlighted in blue. Most sources within this range coincide with observed ^{13}CO clouds. The average mass of the ^{13}CO clouds in this range is $9.6 \times 10^5 M_{\odot}$.

Highlighted in yellow are two different distance ranges that share the velocity range 30–60 km s^{-1} . Sources and clouds coincide in both of these ranges but it is apparent that the more massive ^{13}CO clouds lie at the far distances of the KDA. The average mass of the ^{13}CO clouds at the near distance is $2.8 \times 10^4 M_{\odot}$. At the far distance this quantity is $1.6 \times 10^5 M_{\odot}$. Since there are more massive ^{13}CO clouds and more H II regions at the far distance, the diffuse ^{13}CO emission in Figure 4.1 is likely to be at the far distance.

Chapter 5

Summary

When we observe an H II region that lies at the same position as strong emission from the WIM, we detect multiple RRL components in the resulting spectrum. If we know which of these components originates from the compact H II region, we can use this knowledge in conjunction with a hydrogen absorption spectrum to assign the source a kinematic distance. To determine the correct source velocities we made off-target observations at least one GBT, X-band beam width away from our sources, sampling only the diffuse ionized emission.

We determined the correct source velocity for 93 of 116 sources observed with multiple velocity components. Of those 93 sources, we resolved the KDA for 76 of them that did not lie at the tangent point distance. Twenty-seven are at the near distance and 49 are at the far distance. This is in agreement with results from the HRDS (Anderson et al., 2012).

Knowing the dynamics of the H II regions and ionized gas in the

Galaxy lends insight into the structure and evolution of our Galaxy. The velocities not from compact H II regions are from the WIM. These observations, although the spatial sampling is sparse, are the highest resolution radio observations of the WIM. The WIM is found at multiple velocities throughout the Galaxy. Our analysis showed that the WIM observed at $\sim 50 \text{ km s}^{-1}$ lies at the far kinematic distance, about 12 kpc away. This means we can detect the WIM throughout the entire Galactic disk.

Chapter 6

Tables and Comments on Individual Sources

6.1 Tables

Table 6.1: HII Region Line Parameters

Source	ℓ	b	T_L	σ_{TL}	V_{lsr}	σ_{Vlsr}	ΔV	$\sigma_{\Delta V}$	RMS
	deg.	deg.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK
G021.558−0.112	21.558	−0.112	5.4	0.4	65.1	0.5	9.2	1.4	2.2
G021.558−0.112	21.558	−0.112	5.4	0.4	65.1	0.5	9.2	1.4	2.2
G021.558−0.112	21.558	−0.112	24.9	0.3	115.1	0.2	23.0	0.5	2.2
G023.200+0.000	23.200	0.000	13.4	0.4	89.5	0.5	33.0	1.5	2.3
G023.909+0.066	23.909	0.066	49.0	1.0	38.4	0.1	24.5	0.3	2.2
G023.909+0.066	23.909	0.066	33.0	1.0	107.9	0.2	26.6	0.5	2.2
G024.300−0.149	24.300	−0.149	70.0	0.5	56.8	0.1	17.5	0.1	2.4
G024.300−0.149	24.300	−0.149	30.1	0.5	95.0	0.1	19.1	0.3	2.4
G024.400−0.190	24.400	−0.190	11.9	0.6	54.7	0.7	27.9	1.7	2.4
G024.400−0.190	24.400	−0.190	45.1	0.6	101.0	0.2	21.8	0.4	2.4
G024.507−0.222	24.507	−0.222	25.3	1.8	42.2	0.6	17.2	1.4	8.5
G024.507−0.222	24.507	−0.222	232.4	1.6	96.3	0.1	23.7	0.2	8.5
G024.680−0.160	24.680	−0.160	44.9	0.6	43.6	0.1	13.1	0.2	2.1
G024.680−0.160	24.680	−0.160	421.1	0.5	110.3	0.0	23.4	0.0	2.1
G024.744−0.206	24.744	−0.206	24.6	1.0	44.0	0.3	13.5	0.6	2.9
G024.744−0.206	24.744	−0.206	162.7	0.8	82.6	0.0	19.5	0.1	2.9
G024.744−0.206	24.744	−0.206	17.1	0.4	122.6	0.2	17.8	0.6	2.9
G024.909+0.432	24.909	0.432	28.8	0.7	108.6	0.3	18.2	0.6	2.6
G024.909+0.432	24.909	0.432	13.9	0.5	135.1	0.8	27.4	1.9	2.6
G025.160+0.059	25.160	0.059	66.3	0.4	45.5	0.1	25.1	0.2	2.4
G025.160+0.059	25.160	0.059	9.2	0.4	107.7	0.5	24.8	1.5	2.4
G025.460−0.210	25.460	−0.210	15.4	0.4	62.5	0.4	31.6	0.9	2.2
G025.460−0.210	25.460	−0.210	56.6	0.4	117.3	0.1	30.5	0.2	2.2

Table 6.1: HII Region Line Parameters

Source	ℓ	b	T_L	σ_{TL}	V_{lsr}	σ_{Vlsr}	ΔV	$\sigma_{\Delta V}$	RMS
	deg.	deg.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK
G025.700+0.030	25.700	0.030	195.4	0.9	52.7	0.0	21.3	0.1	2.9
G025.700+0.030	25.700	0.030	19.8	0.4	83.4	0.4	20.7	1.6	2.9
G025.700+0.030	25.700	0.030	49.6	1.2	124.2	0.2	13.2	0.4	2.9
G026.100-0.071	26.10	-0.071	77.2	0.6	30.7	0.1	27.4	0.3	2.3
G026.100-0.071	26.100	-0.071	25.6	0.6	103.4	0.3	30.0	0.8	2.3
G026.599-0.019	26.599	-0.019	33.3	0.5	19.4	0.2	25.7	0.4	2.1
G026.599-0.019	26.599	-0.019	10.9	0.4	102.3	0.6	33.5	1.4	2.1
G027.189-0.079	27.189	-0.079	20.0	0.3	27.8	0.2	22.8	0.5	1.9
G027.189-0.079	27.189	-0.079	10.6	0.3	86.9	0.4	34.7	1.1	1.9
G028.303-0.388	28.303	-0.388	148.7	0.5	76.9	0.0	21.2	0.1	2.9
G028.609+0.021	28.609	0.021	10.0	0.6	40.3	0.5	15.4	1.1	3.3
G028.609+0.021	28.609	0.021	161.2	0.6	96.6	0.0	20.5	0.1	3.3
G029.981-0.607	29.981	-0.607	45.1	0.4	90.9	0.1	19.6	0.2	1.9
G030.470-0.040	30.470	-0.040	62.9	0.7	42.7	0.1	22.1	0.3	2.6
G030.470-0.040	30.470	-0.040	33.8	0.5	101.4	0.3	32.3	0.6	2.6
G030.698-0.628	30.698	-0.628	19.0	0.4	87.8	0.3	16.5	0.9	2.0
G030.698-0.628	30.698	-0.628	8.6	0.4	110.2	0.8	20.1	2.4	2.0
G031.054+0.088	31.054	0.088	95.3	0.7	20.1	0.1	28.2	0.2	2.9
G031.054+0.088	31.054	0.088	33.0	0.6	97.8	0.4	36.1	1.0	2.9
G031.070+0.050	31.070	0.050	109.5	0.6	35.4	0.1	29.0	0.2	2.9
G031.070+0.050	31.070	0.050	39.8	0.5	98.6	0.2	34.6	0.5	2.9
G031.240-0.110	31.240	-0.110	155.6	0.9	26.5	0.1	29.5	0.2	3.0
G031.240-0.110	31.240	-0.110	18.1	0.5	90.3	0.5	29.5	1.5	3.0
G031.600-0.232	31.600	-0.232	35.6	0.4	40.8	0.1	19.6	0.3	2.5
G031.600-0.232	31.600	-0.232	12.6	0.4	100.9	0.3	20.0	0.7	2.5
G031.607+0.334	31.607	0.334	44.9	0.4	24.4	0.1	24.3	0.2	2.6
G031.607+0.334	31.607	0.334	6.1	0.4	96.4	0.9	28.8	2.2	2.6
G031.816-0.121	31.816	-0.121	38.8	0.5	36.3	0.1	20.8	0.3	2.6
G031.816-0.121	31.816	-0.121	11.6	0.5	104.3	0.4	21.6	1.1	2.6
G032.379+0.102	32.379	0.102	15.2	0.3	47.3	0.3	25.8	0.7	1.9
G034.750+0.020	34.750	0.020	25.4	0.5	52.0	0.2	21.0	0.5	2.7
G034.750+0.020	34.750	0.020	36.0	0.5	86.1	0.1	20.2	0.3	2.7
G036.909+0.491	36.909	0.491	11.7	0.4	-32.5	0.4	23.5	1.0	1.8

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
18.695	-0.274	2.5	11.7	0.8	40.5	1.1	19.4	2.2	3.5	G018.677-0.236
18.695	-0.274	2.5	15.7	0.6	64.8	1.0	23.4	2.0	3.5	G018.677-0.236
19.718	0.178	11.8	8.3	0.4	122.4	0.3	15.1	0.9	2.6	G019.594+0.024
19.722	-0.078	2.1	11.1	0.5	56.9	0.5	22.5	1.1	2.4	G019.728-0.113
19.722	-0.078	2.1	13.5	0.4	116.3	0.4	22.5	1.1	2.4	G019.728-0.113
19.822	-0.030	2.5	6.6	0.3	61.9	0.5	21.3	1.3	2.3	G019.813+0.010
19.822	-0.030	2.5	11.9	0.5	120.0	0.3	15.5	0.8	2.3	G019.813+0.010
21.557	-0.049	3.8	5.3	0.4	70.3	0.8	18.1	2.1	2.1	G021.558-0.112
21.557	-0.049	3.8	5.7	0.3	106.4	1.1	34.1	3.0	2.1	G021.558-0.112
21.745	-0.076	2.6	3.4	0.5	19.5	1.3	15.5	3.5	2.3	G021.744-0.032
21.745	-0.076	2.6	4.1	0.5	60.7	0.9	16.8	2.1	2.3	G021.744-0.032
21.745	-0.076	2.6	3.5	0.5	95.5	1.0	16.2	2.5	2.3	G021.744-0.032
21.916	0.064	2.5	5.1	0.3	60.5	1.1	31.0	3.8	2.3	G021.933+0.103
21.985	0.137	3.8	4.7	0.3	57.2	1.5	31.9	4.9	2.2	G021.933+0.103
22.700	-0.269	2.5	13.9	0.5	71.2	0.4	20.2	1.0	2.5	G022.730-0.239, G022.755-0.246
22.700	-0.269	2.5	5.9	0.6	111.2	0.7	14.7	1.8	2.5	G022.730-0.239, G022.755-0.246
22.703	-0.346	3.4	17.2	0.3	71.8	0.3	29.8	0.6	2.3	G022.739-0.303
22.738	-0.189	3.0	14.7	0.4	72.5	0.3	27.4	0.8	2.7	G022.730-0.239, G022.755-0.246
22.781	-0.296	2.6	31.2	0.6	67.5	0.2	17.2	0.5	2.4	G022.739-0.303
22.781	-0.296	2.6	20.6	0.5	99.4	0.4	29.8	1.3	2.4	G022.739-0.303
22.811	-0.202	5.3	21.2	0.3	71.3	0.2	23.7	0.5	2.2	G022.730-0.239, G022.755-0.246
22.811	-0.202	5.3	14.4	0.5	95.1	0.2	10.8	0.6	2.2	G022.730-0.239, G022.755-0.246
22.811	-0.202	5.3	14.6	0.4	112.9	0.2	13.6	0.6	2.2	G022.730-0.239, G022.755-0.246
22.930	-0.149	3.3	10.6	0.2	79.5	0.6	44.1	1.3	1.8	G022.986-0.149

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
22.930	-0.149	3.3	8.5	0.5	101.5	0.2	8.8	0.7	1.8	G022.986-0.149
23.004	-0.194	2.9	21.4	0.4	71.6	0.3	19.6	0.8	2.1	G022.986-0.149
23.004	-0.194	2.9	11.9	0.4	94.4	0.6	19.5	1.3	2.1	G022.986-0.149
23.037	-0.117	3.6	9.1	0.2	81.2	0.7	44.9	1.9	2.1	G022.986-0.149
23.225	-0.344	3.5	17.3	0.3	78.6	0.4	41.5	1.0	1.9	G023.265-0.301
23.241	0.003	2.5	7.0	0.4	82.4	0.6	19.6	1.6	2.0	G023.200+0.000
23.372	-0.110	2.5	9.8	0.4	55.1	0.3	15.0	0.7	2.1	G023.389-0.148
23.372	-0.110	2.5	19.6	0.3	90.7	0.2	20.6	0.4	2.1	G023.389-0.148
23.481	-0.216	2.6	14.6	0.4	57.1	0.3	18.4	0.7	2.2	G023.458-0.179, G023.513-0.244
23.481	-0.216	2.6	19.6	0.4	96.0	0.2	19.0	0.5	2.2	G023.458-0.179, G023.513-0.244
23.588	-0.239	2.5	5.8	0.4	55.5	1.2	25.1	3.4	2.4	G023.604-0.200
23.588	-0.239	2.5	9.3	0.3	95.4	0.9	36.0	2.4	2.4	G023.604-0.200
23.720	-0.055	2.2	13.1	0.6	106.1	0.5	21.9	1.2	3.3	G023.736-0.022
23.845	0.061	2.6	13.7	0.3	106.3	0.6	41.8	1.8	1.9	G023.836+0.104
23.860	0.037	3.4	11.4	0.3	98.5	0.5	23.9	1.7	2.6	G023.909+0.066
23.860	0.037	3.4	20.5	0.5	117.2	0.2	12.6	0.4	2.6	G023.909+0.066
24.158	0.242	2.3	22.6	0.8	111.5	0.3	17.1	0.7	2.3	G024.197+0.245
24.346	-0.139	2.9	16.1	0.4	54.4	0.2	18.0	0.5	2.0	G024.300-0.149
24.346	-0.139	2.9	22.8	0.4	94.0	0.1	19.0	0.3	2.0	G024.300-0.149
24.369	-0.225	2.8	7.0	0.3	54.4	0.7	29.2	1.8	1.8	G024.400-0.190
24.369	-0.225	2.8	24.8	0.4	96.4	0.2	18.9	0.4	1.8	G024.400-0.190
24.425	-0.177	1.7	6.4	0.4	54.4	0.7	22.0	1.7	2.1	G024.400-0.190
24.425	-0.177	1.7	28.0	0.4	100.3	0.2	24.8	0.4	2.1	G024.400-0.190

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
24.470	-0.322	2.4	9.1	0.5	49.6	0.6	21.2	1.4	2.3	G024.430-0.320
24.470	-0.322	2.4	13.9	0.6	96.5	0.3	16.0	0.8	2.3	G024.430-0.320
24.476	-0.198	2.4	9.6	0.4	46.6	0.5	26.9	1.2	2.2	G024.507-0.222
24.476	-0.198	2.4	28.1	0.4	94.7	0.2	20.4	0.4	2.2	G024.507-0.222
24.476	-0.198	2.4	8.7	0.4	123.8	0.5	17.8	1.3	2.2	G024.507-0.222
24.498	-0.182	2.5	20.7	2.2	52.9	0.5	10.0	1.2	7.6	G024.507-0.222
24.498	-0.182	2.5	45.2	2.5	89.9	0.2	7.8	0.5	7.6	G024.507-0.222
24.512	0.538	3.2	11.6	0.5	34.2	0.3	11.9	0.7	2.0	G024.500+0.487
24.512	0.538	3.2	8.8	0.4	100.5	0.4	17.3	1.0	2.0	G024.500+0.487
24.518	-0.152	2.6	10.7	0.4	52.3	0.5	27.9	1.5	2.1	G024.557-0.132
24.518	-0.152	2.6	23.8	0.4	92.3	0.2	27.1	0.6	2.1	G024.557-0.132
24.634	-0.183	3.1	51.9	0.8	42.5	0.1	13.1	0.2	2.6	G024.680-0.160
24.634	-0.183	3.1	13.1	0.4	109.9	1.1	53.4	2.8	2.6	G024.680-0.160
24.637	-0.109	4.7	21.0	0.9	42.4	0.2	10.2	0.6	2.7	G024.713-0.125
24.637	-0.109	4.7	59.9	1.5	104.5	0.3	23.4	0.7	2.7	G024.713-0.125
24.638	-0.183	2.9	51.8	0.8	42.5	0.1	13.1	0.2	2.5	G024.680-0.160
24.638	-0.183	2.9	12.8	0.4	109.7	1.1	52.2	2.8	2.5	G024.680-0.160
24.694	0.144	2.6	12.7	0.4	81.4	0.2	14.1	0.6	2.1	G024.735+0.159
24.694	0.144	2.6	23.1	0.4	109.6	0.2	23.3	0.6	2.1	G024.735+0.159
24.784	-0.178	2.9	22.9	0.5	40.9	0.1	11.4	0.3	2.5	G024.744-0.206
24.784	-0.178	2.9	12.7	0.3	113.8	0.4	29.0	1.0	2.5	G024.744-0.206
24.784	-0.178	2.9	27.9	0.9	40.4	0.2	10.1	0.4	2.6	G024.744-0.206
24.784	-0.178	2.9	19.3	0.5	115.1	0.4	29.0	0.9	2.6	G024.744-0.206
24.799	-0.151	5.4	15.1	0.6	40.9	0.3	16.5	0.8	2.1	G024.713-0.125

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
24.799	-0.151	5.4	15.4	0.4	110.4	0.4	30.8	1.0	2.1	G024.713-0.125
24.902	-0.065	3.3	8.0	0.4	50.9	0.5	16.9	1.4	2.0	G024.955-0.048
24.902	-0.065	3.3	13.4	0.4	99.0	0.5	28.8	1.1	2.0	G024.955-0.048
24.906	0.039	2.6	14.7	0.4	109.7	0.3	23.6	0.8	2.3	G024.923+0.079
24.965	0.391	4.2	11.9	0.4	111.1	0.3	18.2	0.7	1.9	G024.909+0.432
25.128	0.121	2.2	15.8	0.5	95.2	0.4	25.7	1.2	2.3	G025.150+0.092
25.155	-0.372	2.2	6.2	0.5	123.9	0.6	15.0	1.4	2.3	G025.143-0.338
25.205	0.045	2.8	9.6	0.3	50.9	0.6	33.8	1.7	2.1	G025.160+0.059
25.205	0.045	2.8	8.3	0.4	104.5	0.6	29.0	1.6	2.1	G025.160+0.059
25.308	0.494	2.3	5.2	0.3	40.4	0.8	24.3	1.8	2.1	G025.305+0.532
25.387	0.521	2.5	5.6	0.4	43.0	0.6	18.8	1.5	2.4	G025.398+0.562
25.492	-0.193	2.2	10.4	0.3	62.6	0.5	33.2	1.4	2.1	G025.460-0.210
25.492	-0.193	2.2	16.1	0.4	107.3	0.4	24.8	1.2	2.1	G025.460-0.210
25.493	-0.165	3.0	7.3	0.4	68.9	0.9	26.9	2.8	2.6	G025.469-0.121
25.493	-0.165	3.0	17.9	0.3	110.8	0.2	27.7	0.7	2.6	G025.469-0.121
25.495	-0.001	2.7	12.1	0.4	56.4	0.7	27.4	1.5	1.9	G025.477+0.040
25.495	-0.001	2.7	5.8	0.4	100.5	1.7	41.4	5.1	1.9	G025.477+0.040
25.505	-0.075	3.5	13.8	0.6	60.8	0.6	29.2	1.5	2.7	G025.469-0.121
25.505	-0.075	3.5	10.9	0.6	107.3	0.7	25.9	1.8	2.7	G025.469-0.121
25.659	0.065	3.2	7.1	0.5	48.3	0.6	15.3	1.4	2.8	G025.700+0.030
25.659	0.065	3.2	8.5	0.4	89.5	0.8	32.9	2.3	2.8	G025.700+0.030
25.659	0.065	3.2	14.7	0.7	120.0	0.3	11.2	0.6	2.8	G025.700+0.030
26.033	-0.073	4.1	6.1	0.2	24.6	1.3	56.3	3.6	2.0	G026.100-0.071

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
26.033	-0.073	4.1	15.0	0.3	107.0	0.3	31.8	0.8	2.0	G026.100-0.071
26.235	0.241	2.8	13.6	0.5	108.0	0.7	35.5	1.9	3.0	G026.261+0.280
26.291	0.242	2.9	9.1	0.3	95.0	0.9	22.7	1.9	2.2	G026.261+0.280
26.291	0.242	2.9	8.2	0.5	117.7	0.9	17.8	1.6	2.2	G026.261+0.280
26.557	-0.036	2.7	8.1	0.3	103.1	0.9	45.3	2.1	2.3	G026.599-0.019
26.560	-0.197	3.1	9.4	0.4	78.3	1.4	41.5	6.6	2.2	G026.610-0.212
26.560	-0.197	3.1	11.6	0.4	102.5	0.9	26.2	2.5	2.2	G026.610-0.212
26.678	0.003	2.3	5.6	0.6	25.1	0.7	14.3	1.7	2.5	G026.644+0.020
26.678	0.003	2.3	16.0	0.6	69.8	0.3	13.1	0.6	2.5	G026.644+0.020
26.678	0.003	2.3	12.0	0.4	101.8	0.6	33.6	1.5	2.5	G026.644+0.020
26.702	0.123	3.0	6.2	0.3	33.1	0.8	31.1	2.2	2.0	G026.721+0.170
26.702	0.123	3.0	5.0	0.4	69.4	1.8	37.8	7.3	2.0	G026.721+0.170
26.702	0.123	3.0	7.5	0.5	103.3	1.0	30.3	3.1	2.0	G026.721+0.170
26.862	-0.224	3.1	14.9	0.6	64.1	0.4	17.1	1.1	2.5	G026.863-0.275
26.862	-0.224	3.1	8.7	0.3	84.6	1.4	33.9	4.5	2.5	G026.863-0.275
27.217	-0.064	1.9	11.7	0.3	91.6	0.4	32.1	1.1	2.4	G027.189-0.079
27.221	-0.155	2.3	13.8	0.5	28.3	0.3	14.4	0.7	3.0	G027.183-0.151
27.221	-0.155	2.3	6.6	0.6	59.7	0.6	12.6	1.5	3.0	G027.183-0.151
27.221	-0.155	2.3	10.2	0.4	89.3	0.7	31.4	1.8	3.0	G027.183-0.151
27.333	0.131	2.7	14.0	0.4	96.7	0.4	26.3	1.2	2.3	G027.334+0.176
27.369	0.234	3.4	5.1	0.5	22.8	0.8	15.3	1.9	3.0	G027.320+0.263
27.369	0.234	3.4	5.1	0.4	84.7	1.7	37.8	4.1	3.0	G027.320+0.263
27.371	-0.125	2.3	17.6	0.4	94.1	0.9	28.2	1.7	2.1	G027.366-0.164
27.371	-0.125	2.3	7.4	0.4	73.0	0.6	21.5	1.6	2.1	G027.366-0.164

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
27.950	-0.005	2.7	2.9	0.3	40.6	1.2	21.5	3.0	1.6	G027.906-0.010
27.950	-0.005	2.7	4.0	0.2	95.3	1.3	44.1	3.8	1.6	G027.906-0.010
27.962	0.198	1.7	6.4	0.5	38.2	0.4	11.2	1.0	2.3	G027.934+0.206
27.962	0.198	1.7	10.0	0.3	92.6	0.4	26.8	1.1	2.3	G027.934+0.206
28.260	-0.027	3.0	7.4	0.6	42.5	0.4	9.0	0.9	2.4	G028.291+0.012
28.260	-0.027	3.0	18.8	0.4	77.2	0.4	23.1	1.0	2.4	G028.291+0.012
28.260	-0.027	3.0	12.2	0.4	103.1	0.6	20.0	1.3	2.4	G028.291+0.012
28.282	0.059	2.9	14.5	0.3	93.4	0.4	41.3	1.2	2.3	G028.291+0.012
28.351	0.085	2.6	29.5	0.4	91.5	0.2	30.7	0.6	2.3	G028.394+0.076
28.382	0.035	2.6	6.2	0.4	45.7	0.5	16.6	1.2	2.0	G028.394+0.076
28.382	0.035	2.6	24.9	0.3	89.0	0.2	28.1	0.4	2.0	G028.394+0.076
28.582	0.105	2.4	7.2	0.4	24.6	0.7	26.9	1.7	2.2	G028.581+0.145
28.582	0.105	2.4	6.4	0.3	91.4	0.8	31.6	1.9	2.2	G028.581+0.145
28.644	-0.045	4.5	13.9	0.5	97.4	0.4	22.6	1.1	2.5	G028.609+0.021
28.648	0.429	3.1	4.3	0.4	28.9	1.2	23.8	3.1	2.4	G028.638+0.479
28.648	0.429	3.1	7.1	0.8	64.1	0.4	7.7	1.0	2.4	G028.638+0.479
28.648	0.429	3.1	9.7	0.5	94.7	0.5	22.2	1.2	2.4	G028.638+0.479
28.737	0.068	2.7	7.3	0.4	46.4	0.9	30.4	2.7	2.5	G028.696+0.048
28.737	0.068	2.7	8.8	0.5	98.7	0.6	20.2	1.4	2.5	G028.696+0.048
28.798	0.328	3.5	30.9	0.5	81.8	0.2	22.1	0.5	2.5	G028.764+0.281
28.798	0.328	3.5	14.3	0.4	101.6	0.5	17.5	1.3	2.5	G028.764+0.281
29.180	-0.139	2.8	4.4	0.3	58.6	1.7	41.7	6.4	2.0	G029.134-0.145
29.180	-0.139	2.8	3.7	0.5	97.9	1.3	19.3	3.1	2.0	G029.134-0.145

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
29.390	0.300	3.1	4.1	0.3	27.8	1.3	36.5	3.3	1.8	G029.433+0.273
29.390	0.300	3.1	5.0	0.3	95.3	0.7	20.7	1.6	1.8	G029.433+0.273
29.401	-0.376	4.7	3.4	0.4	43.5	1.1	20.2	2.7	2.4	G029.344-0.430
29.401	-0.376	4.7	4.1	0.3	96.0	1.4	42.5	3.8	2.4	G029.344-0.430
29.408	0.240	2.5	8.0	0.3	40.3	0.6	30.3	1.5	2.3	G029.433+0.273
29.408	0.240	2.5	7.7	0.4	100.2	0.5	19.5	1.2	2.3	G029.433+0.273
29.774	0.175	2.6	9.7	0.9	80.9	0.4	9.6	1.0	2.5	G029.770+0.219
30.045	-0.593	3.9	12.1	0.3	94.1	0.3	21.9	0.6	2.1	G029.981-0.607
30.260	0.195	2.9	7.6	0.4	94.1	1.2	38.9	3.3	2.2	G030.249+0.243
30.293	0.030	2.8	46.4	0.8	104.3	0.2	22.4	0.4	2.6	G030.252+0.051
30.399	0.056	3.3	22.0	0.4	103.3	0.2	26.6	0.7	2.2	G030.378+0.106, G030.345+0.092 G030.374+0.026
30.402	0.137	2.3	9.7	0.5	67.4	0.7	21.1	2.1	2.1	G030.378+0.106, G030.345+0.092 G030.374+0.026
30.402	0.137	2.3	8.8	0.6	88.5	0.6	12.6	1.6	2.1	G030.378+0.106, G030.345+0.092 G030.374+0.026
30.402	0.137	2.3	25.7	0.5	109.9	0.2	18.3	0.5	2.1	G030.378+0.106, G030.345+0.092 G030.374+0.026
30.526	-0.034	3.4	10.8	0.4	57.6	0.4	21.6	1.7	2.3	G030.470-0.040
30.526	-0.034	3.4	20.0	1.2	87.8	0.3	13.7	1.0	2.3	G030.470-0.040
30.526	-0.034	3.4	25.8	0.4	106.6	0.6	24.4	1.3	2.3	G030.470-0.040
30.425	-0.038	2.7	26.7	0.5	90.6	0.4	23.7	1.3	2.8	G030.470-0.040
30.425	-0.038	2.7	48.4	1.2	107.9	0.1	10.0	0.2	2.8	G030.470-0.040

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
30.442	-0.165	2.0	22.3	0.8	81.3	0.3	17.1	0.9	2.3	G030.463-0.191
30.442	-0.165	2.0	16.2	0.3	107.6	0.6	44.1	3.3	2.3	G030.463-0.191
30.575	-0.242	2.8	38.1	0.5	88.3	0.1	19.5	0.3	2.5	G030.532-0.259
30.629	0.015	2.1	7.3	0.4	40.9	0.7	24.3	1.7	2.2	G030.597+0.030
30.629	0.015	2.1	19.9	0.4	102.3	0.3	33.0	0.9	2.2	G030.597+0.030, G030.644+0.053
30.658	0.315	4.2	10.9	0.4	71.7	0.5	28.2	1.3	2.5	G030.696+0.256
30.658	0.315	4.2	12.6	0.5	111.5	0.3	17.6	0.8	2.5	G030.696+0.256
30.720	0.225	2.7	7.7	0.5	38.5	0.5	17.8	1.2	1.9	G030.760+0.206, G030.797+0.165
										G030.838+0.114, G030.852+0.149
30.720	0.225	2.7	25.8	0.4	98.5	0.2	28.6	0.5	1.9	G030.760+0.206, G030.797+0.165
										G030.838+0.114, G030.852+0.149
30.720	-0.210	3.1	13.4	0.4	95.4	0.4	26.6	1.1	3.5	G030.771-0.223
30.734	-0.605	2.6	4.6	1.1	79.9	0.6	10.1	2.5	1.9	G030.698-0.628
30.734	-0.605	2.6	9.9	0.3	97.1	1.2	32.5	3.7	1.9	G030.698-0.628
30.759	0.175	1.9	4.7	0.3	34.2	0.9	27.8	2.2	2.4	G030.760+0.206, G030.797+0.165
										G030.838+0.114, G030.852+0.149
30.759	0.175	1.9	11.6	0.4	88.7	0.5	17.4	1.2	2.4	G030.760+0.206, G030.797+0.165
										G030.838+0.114, G030.852+0.149
30.759	0.175	1.9	6.6	0.6	112.6	2.5	17.4	6.5	2.4	G030.760+0.206, G030.797+0.165
										G030.838+0.114, G030.852+0.149
30.777	0.247	2.7	22.2	0.4	35.6	0.2	20.2	0.5	2.3	G030.760+0.206, G030.797+0.165
										G030.838+0.114, G030.852+0.149
30.777	0.247	2.7	6.3	0.3	96.0	1.7	50.2	3.3	2.3	G030.760+0.206, G030.797+0.165

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
30.777	0.247	2.7	5.7	0.7	114.1	0.6	10.7	1.7	2.3	G030.838+0.114, G030.852+0.149 G030.760+0.206, G030.797+0.165 G030.838+0.114, G030.852+0.149
30.823	-0.282	4.7	4.8	0.7	49.7	1.1	16.5	2.6	3.4	G030.771-0.223
30.823	-0.282	4.7	22.7	0.5	92.4	0.3	25.3	0.7	3.4	G030.771-0.223
30.903	0.127	2.2	6.7	0.3	36.4	0.6	30.2	1.6	1.8	G030.902+0.164
30.903	0.127	2.2	41.4	0.6	103.9	0.2	34.2	0.6	1.8	G030.902+0.164
30.915	0.054	2.2	16.2	0.8	38.1	0.5	19.5	1.1	2.6	G030.883+0.071, G030.907+0.016
30.915	0.054	2.2	53.1	0.6	99.2	0.2	30.9	0.4	2.6	G030.883+0.071, G030.907+0.016
30.921	0.572	2.6	5.9	0.3	94.1	0.9	33.2	2.4	2.2	G030.951+0.541, G030.956+0.599
31.020	0.117	2.7	18.1	0.4	38.6	0.4	32.8	1.0	2.3	G031.054+0.088
31.020	0.117	2.7	21.0	1.1	84.0	0.5	15.1	0.9	2.3	G031.054+0.088
31.020	0.117	2.7	42.5	0.6	102.7	0.4	20.9	0.7	2.3	G031.054+0.088
31.078	0.175	3.4	11.2	0.3	43.2	0.4	24.2	0.9	2.1	G031.104+0.125, G031.140+0.121 G031.159+0.048
31.078	0.175	3.4	22.6	0.4	84.0	0.2	18.1	0.6	2.1	G031.104+0.125, G031.140+0.121 G031.159+0.048
31.078	0.175	3.4	25.5	0.4	108.2	0.2	19.5	0.5	2.1	G031.104+0.125, G031.140+0.121 G031.159+0.048
31.109	-0.151	2.9	7.0	0.6	20.1	0.8	15.1	2.2	3.3	G031.157-0.148
31.109	-0.151	2.9	64.1	0.5	43.7	0.1	18.1	0.2	3.3	G031.157-0.148
31.109	-0.151	2.9	5.3	0.5	98.9	0.9	18.6	2.2	3.3	G031.157-0.148
31.110	0.055	2.4	29.1	0.3	34.7	0.2	31.3	0.4	2.4	G031.070+0.050

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
31.110	0.055	2.4	26.4	0.8	84.1	0.1	7.6	0.3	2.4	G031.070+0.050
31.110	0.055	2.4	26.1	0.3	99.4	0.3	32.7	0.6	2.4	G031.070+0.050
31.093	0.000	3.3	20.1	0.4	34.1	0.3	35.5	0.8	2.7	G031.070+0.050
31.093	0.000	3.3	33.7	0.6	90.5	0.3	18.7	0.5	2.7	G031.070+0.050
31.093	0.000	3.3	36.9	0.5	114.2	0.3	21.2	0.6	2.7	G031.070+0.050
31.128	0.084	2.9	12.6	0.4	40.9	0.6	21.3	1.4	2.9	G031.104+0.125, G031.140+0.121 G031.159+0.048
31.128	0.084	2.9	19.9	0.9	83.9	0.3	13.1	0.6	2.9	G031.104+0.125, G031.140+0.121 G031.159+0.048
31.128	0.084	2.9	26.4	0.4	104.3	0.4	25.5	0.9	2.9	G031.104+0.125, G031.140+0.121 G031.159+0.048
31.129	0.168	3.0	6.7	0.3	45.4	0.8	35.1	2.7	2.0	G031.104+0.125, G031.140+0.121 G031.159+0.048
31.129	0.168	3.0	10.9	1.5	83.3	0.6	13.9	1.3	2.0	G031.104+0.125, G031.140+0.121 G031.159+0.048
31.129	0.168	3.0	15.3	0.4	100.5	1.0	23.5	1.9	2.0	G031.104+0.125, G031.140+0.121 G031.159+0.048
31.167	-0.177	1.9	10.9	0.4	44.2	0.3	18.7	0.8	2.2	G031.157-0.148
31.167	-0.177	1.9	9.7	0.3	94.2	0.5	29.6	1.2	2.2	G031.157-0.148
31.172	0.097	2.1	14.1	0.6	43.1	0.4	16.6	1.0	2.5	G031.207+0.098
31.172	0.097	2.1	21.6	0.6	101.2	0.3	26.5	0.9	2.5	G031.207+0.098
31.198	0.133	2.2	8.0	0.4	43.0	0.9	35.1	2.4	2.0	G031.207+0.098
31.198	0.133	2.2	16.7	0.4	100.8	0.4	30.9	1.2	2.0	G031.207+0.098
31.207	0.061	2.2	8.7	0.4	43.0	0.4	18.8	1.0	2.8	G031.207+0.098

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
31.207	0.061	2.2	29.0	0.5	100.8	0.2	22.4	0.5	2.8	G031.207+0.098
31.232	-0.065	2.8	16.2	0.3	34.4	0.4	42.5	1.2	2.2	G031.240-0.110
31.232	-0.065	2.8	7.5	0.6	77.2	0.6	12.8	1.5	2.2	G031.240-0.110
31.232	-0.065	2.8	16.6	0.4	99.3	0.4	21.9	1.0	2.2	G031.240-0.110
31.233	-0.070	2.4	17.0	0.3	33.7	0.4	45.8	1.3	3.0	G031.240-0.110
31.233	-0.070	2.4	9.2	0.8	79.8	0.4	9.9	1.1	3.0	G031.240-0.110
31.233	-0.070	2.4	15.2	0.5	98.7	0.4	21.4	1.1	3.0	G031.240-0.110
31.416	-0.106	2.2	6.2	0.4	80.0	3.9	43.7	8.4	2.3	G031.425-0.141
31.416	-0.106	2.2	18.2	0.6	97.1	0.3	18.8	0.8	2.3	G031.425-0.141
31.517	-0.068	2.9	7.3	0.6	98.3	0.7	15.7	1.6	2.5	G031.535-0.113
31.566	0.270	4.5	5.1	0.3	87.4	1.0	27.0	3.4	2.1	G031.607+0.334
31.566	0.270	4.5	5.7	0.4	116.1	0.5	12.8	1.3	2.1	G031.607+0.334
31.631	-0.291	4.0	9.8	0.3	96.6	0.4	23.2	1.0	2.3	G031.600-0.232
31.760	-0.112	3.4	10.3	0.6	42.2	0.4	16.1	1.0	2.1	G031.816-0.121
31.760	-0.112	3.4	35.1	0.6	94.8	0.1	12.7	0.3	2.1	G031.816-0.121
31.760	-0.112	3.4	9.5	0.8	110.1	0.4	8.5	1.0	2.1	G031.816-0.121
32.057	0.007	4.0	4.3	0.5	39.5	2.1	28.3	5.3	2.9	G032.108+0.050
32.057	0.007	4.0	6.4	0.5	91.4	0.8	20.7	2.0	2.9	G032.108+0.050
32.155	0.011	3.7	23.7	0.6	41.8	0.2	13.6	0.4	1.9	G032.108+0.050
32.155	0.011	3.7	10.5	0.6	95.1	0.3	11.6	0.8	1.9	G032.108+0.050
32.552	-0.048	2.4	7.2	0.6	27.8	0.6	13.6	1.4	2.4	G032.581-0.077
32.552	-0.048	2.4	5.0	0.5	101.4	1.0	17.8	2.3	2.4	G032.581-0.077
33.790	-0.088	2.7	6.0	0.4	48.4	1.4	47.8	4.1	2.2	G033.753-0.063

Table 6.2: Line Parameters of Diffuse Emission

ℓ	b	Separation	T_L	σ_{TL}	V_{lsr}	σ_{vlsr}	ΔV	$\sigma_{\Delta V}$	RMS	HII Region
deg.	deg.	arcmin.	mK	mK	km s ⁻¹	km s ⁻¹	km s ⁻¹	km s ⁻¹	mK	
33.790	-0.088	2.7	5.6	0.5	102.0	1.1	22.5	3.0	2.2	G033.753-0.063
33.965	0.025	2.5	5.6	0.3	43.6	1.0	34.4	2.1	2.0	G033.994-0.006
33.965	0.025	2.5	4.5	0.8	58.7	0.4	4.9	1.0	2.0	G033.994-0.006
34.065	-0.092	2.9	10.6	0.3	40.0	0.3	21.2	0.7	2.2	G034.031-0.059
34.750	-0.041	3.7	7.9	0.3	52.8	0.5	28.6	1.3	2.1	G034.750+0.020
34.765	0.074	3.4	14.6	0.4	53.2	0.3	19.5	0.7	2.2	G034.750+0.020
34.765	0.074	3.4	17.9	0.5	83.1	0.2	13.8	0.5	2.2	G034.750+0.020
34.822	0.024	4.3	9.5	0.3	50.6	0.5	27.1	1.7	2.2	G034.750+0.020
34.822	0.024	4.3	8.2	0.4	83.5	0.5	17.5	1.2	2.2	G034.750+0.020
35.220	0.093	3.0	3.9	0.3	56.2	2.2	38.7	6.5	1.8	G035.260+0.122
35.305	0.104	2.9	6.2	0.5	46.3	0.5	14.3	1.3	1.8	G035.260+0.122
36.953	0.102	4.6	4.1	0.2	39.2	0.8	35.4	1.9	1.5	G037.027+0.123
37.367	-0.353	4.0	3.4	0.4	34.7	1.1	20.4	2.8	2.1	G037.432-0.337
37.459	-0.409	4.6	6.0	0.4	47.7	0.3	9.5	0.8	2.1	G037.432-0.337
38.110	-0.200	1.7	18.4	0.6	53.9	0.2	12.0	0.5	2.5	G038.120-0.227
38.110	-0.200	1.7	8.1	0.6	71.9	0.5	11.7	1.2	2.5	G038.120-0.227
37.546	0.543	4.1	5.9	0.2	45.8	0.5	24.7	1.5	1.9	G037.485+0.513
50.057	-0.143	3.7	6.4	0.3	64.7	0.3	11.9	0.7	1.9	G049.998-0.125

Table 6.3: HII Region Velocities and Distances

Source	V_{lsr} km s ⁻¹	D_N kpc	D_F kpc	KDAR	QF	R_{gal} kpc	D kpc	z pc	Reason ¹
G018.677-0.236	42.6	3.5	12.6	F	A	5.3	12.6	-51.8	2,3,6
G019.594+0.024	35.3	3.0	13.0	F	B	5.7	13.0	5.4	...
G019.728-0.113	57.3	4.2	11.8	F	B	4.8	11.8	-23.3	4,6
G019.813+0.010	60.4	4.3	11.7	F	A	4.7	11.7	2.0	2,4
G021.558-0.112	115.1	6.5	9.3	N	A	3.4	6.5	-12.6	2
G021.744-0.032	20.0	1.8	14.0	F	B	6.9	14.0	-7.8	2,6
G021.933+0.103	82.2	5.1	10.6	N	A	4.2	5.1	9.2	6
G022.730-0.239	71.1	4.6	11.0	N	B	4.6	4.6	-19.3	...
G022.739-0.303	112.1	6.4	9.3	F	B	3.6	9.3	-49.2	...
G023.200+0.000	89.5	5.4	10.2	N	A	4.1	5.4	0.0	8
G023.265-0.301	73.1	4.7	10.9	N	B	4.6	4.7	-24.7	4,9
G023.389-0.148	98.5	5.8	9.8	F	B	3.9	9.8	-25.4	2,4
G023.458-0.179	97.4	5.7	9.9	F	B	4.0	9.9	-30.8	2,6
G023.604-0.200	82.7	5.1	10.5	N	B	4.3	5.1	-17.8	2,4
G023.736-0.022	3.0	0.2	15.4	F	A	8.3	15.4	-5.9	3,6
G023.836+0.104	41.9	3.1	12.4	F	B	5.8	12.4	22.5	...
G023.909+0.066	38.4	2.9	12.6	F	A	5.9	12.6	14.6	1,7
G024.197+0.245	34.4	2.7	12.8	F	A	6.2	12.8	54.9	1
G024.300-0.149	56.8	3.9	11.6	N	B	5.2	3.9	-10.2	2
G024.430-0.320	95.8	5.7	9.8	N	B	4.1	5.7	-31.6	4
G024.500+0.487	98.9	5.8	9.7	N	A	4.0	5.8	49.3	9
G024.507-0.222	96.3	5.7	9.8	N	A	4.1	5.7	-22.0	7,9
G024.557-0.132	91.1	5.4	10.0	F	B	4.2	10.0	-23.0	4,6
G024.680-0.160	110.3	6.4	9.1	N	A	3.8	6.4	-17.7	2,7
G024.713-0.125	112.3	6.5	9.0	N	A	3.8	6.5	-14.1	2,6
G024.735+0.159	109.3	6.3	9.1	N	B	3.8	6.3	17.5	2,4,6
G024.744-0.206	82.6	5.1	10.4	F	A	4.4	10.4	-37.2	1
G024.909+0.432	135.1	7.7	7.7	N	A	3.6	7.7	58.0	...
G024.923+0.079	42.4	3.1	12.3	F	A	5.8	12.3	17.0	1,6
G024.955-0.048	49.8	3.5	11.9	F	A	5.5	11.9	-10.0	2
G025.143-0.338	9.5	0.8	14.6	F	B	7.8	14.6	-86.1	3
G025.150+0.092	46.5	3.3	12.1	F	B	5.7	12.1	19.4	1,6
G025.160+0.059	45.5	3.3	12.1	N	B	5.7	3.3	3.4	2,7
G025.305+0.532	7.0	0.6	14.8	F	B	8.0	14.8	137.5	1
G025.398+0.562	12.9	1.1	14.3	F	B	7.6	14.3	140.1	1,3,4,6

Table 6.3: HII Region Velocities and Distances

Source	V_{lsr} km s ⁻¹	D_N kpc	D_F kpc	KDAR	QF	R_{gal} kpc	D kpc	z pc	Reason ¹
G025.460-0.210	117.3	6.9	8.4	T	A	3.7	7.7	-28.1	2,7
G025.469-0.121	96.9	5.7	9.6	N	B	4.1	5.7	-12.1	4
G025.477+0.040	-14.6	...	17.3	F	A	10.3	17.3	12.1	1,5
G025.700+0.030	52.7	3.6	11.7	F	B	5.5	11.7	6.2	9
G026.100-0.071	30.7	2.3	12.9	F	A	6.5	12.9	-15.9	2
G026.599-0.019	19.4	1.5	13.7	F	B	7.2	13.7	-4.4	1
G026.610-0.212	-35.7	...	20.8	F	A	13.8	20.8	-77.1	1,5
G026.644+0.020	108.7	6.4	8.8	T	A	4.0	7.6	2.6	2,6
G026.721+0.170	31.0	2.3	12.9	F	A	6.5	12.9	38.1	2,3,6
G026.863-0.275	69.3	4.4	10.8	N	B	5.0	4.4	-21.2	2,4
G027.183-0.151	27.2	2.1	13.1	F	A	6.7	13.1	-34.4	2
G027.189-0.079	27.8	2.1	13.0	F	B	6.7	13.0	-17.8	1
G027.320+0.263	28.5	2.2	13.0	F	B	6.7	13.0	59.4	2,4
G027.334+0.176	80.4	4.9	10.2	F	B	4.7	10.2	31.2	4
G027.934+0.206	50.6	3.4	11.6	N	B	5.7	3.4	12.3	2,6
G028.291+0.012	44.4	3.1	11.9	N	B	6.0	3.1	0.6	6
G028.303-0.388	76.9	4.8	10.2	F	B	4.9	10.2	-69.1	8
G028.394+0.076	42.8	3.0	12.0	N	A	6.0	3.0	4.0	4
G028.581+0.145	-13.0	...	16.5	F	A	9.9	16.5	41.7	1,5
G028.609+0.021	96.6	5.8	9.1	F	B	4.4	9.1	3.4	9
G028.638+0.479	28.4	2.1	12.8	F	B	6.7	12.8	107.1	2,3,4
G028.696+0.048	100.7	6.1	8.8	N	B	4.3	6.1	5.1	...
G028.764+0.281	104.5	6.4	8.5	T	A	4.2	7.4	36.5	2
G029.134-0.145	48.6	3.3	11.6	N	A	5.8	3.3	-8.3	2
G029.344-0.430	91.6	5.6	9.2	N	A	4.6	5.6	-41.8	2
G029.433+0.273	33.4	2.4	12.4	N	B	6.5	2.4	11.4	3
G029.770+0.219	-31.3	...	18.9	F	A	12.3	18.9	72.1	1,5
G029.981-0.607	90.9	5.6	9.2	F	B	4.6	9.2	-97.0	8
G030.249+0.243	8.9	0.6	14.1	F	A	8.0	14.1	59.6	1
G030.252+0.051	65.2	4.2	10.5	F	A	5.3	10.5	9.4	1,3,6
G030.374+0.026	44.4	3.0	11.6	F	A	6.1	11.6	5.3	1,4
G030.378+0.106	102.0	6.5	8.2	T	A	4.4	7.3	13.6	4,6
G030.463-0.191	107.5	7.3	7.3	T	A	4.3	7.3	-24.4	4
G030.470-0.040	42.7	2.9	11.7	N	A	6.2	2.9	-2.0	...

Table 6.3: HII Region Velocities and Distances

Source	V_{lsr} km s ⁻¹	D_N kpc	D_F kpc	KDAR	QF	R_{gal} kpc	D kpc	z pc	Reason ¹
G030.532-0.259	105.1	7.0	7.7	T	A	4.3	7.3	-33.1	1
G030.597+0.030	44.9	3.0	11.6	F	B	6.1	11.6	6.1	...
G030.696+0.256	102.1	6.6	8.1	T	A	4.4	7.3	32.6	4,9
G030.698-0.628	87.8	5.4	9.2	T	A	4.7	7.3	-80.1	...
G030.760+0.206	98.5	6.2	8.4	T	A	4.5	7.3	26.3	4,6
G030.771-0.223	103.6	6.8	7.8	T	A	4.4	7.3	-28.4	...
G030.797+0.165	40.4	2.8	11.8	F	A	6.3	11.8	34.0	2,4,9
G030.838+0.114	35.8	2.5	12.1	N	B	6.5	2.5	5.0	...
G030.852+0.149	39.6	2.7	11.9	F	A	6.3	11.9	30.8	9
G030.883+0.071	96.5	6.0	8.6	T	A	4.5	7.3	9.0	4
G030.902+0.164	40.6	2.8	11.8	T	A	6.3	7.3	20.9	2,4
G030.951+0.541	24.5	1.8	12.8	F	A	7.0	12.8	120.8	1
G030.956+0.599	23.4	1.7	12.9	F	A	7.1	12.9	134.6	1,4
G031.054+0.088	20.1	1.5	13.1	F	A	7.3	13.1	20.0	2,7
G031.070+0.050	35.4	2.5	12.1	F	A	6.5	12.1	10.5	2
G031.157-0.148	43.6	3.0	11.6	F	A	6.2	11.6	-29.9	6,9
G031.240-0.110	26.5	1.9	12.6	F	A	6.9	12.6	-24.2	2,7
G031.425-0.141	28.8	2.0	12.5	F	B	6.8	12.5	-30.6	1,4
G031.535-0.113	51.1	3.4	11.1	F	B	5.9	11.1	-21.9	1,4
G031.600-0.232	40.8	2.8	11.7	F	B	6.3	11.7	-47.2	1,7
G031.607+0.334	24.4	1.8	12.7	...	C	7.1	...	...	...
G032.108+0.050	94.4	6.0	8.4	T	A	4.7	7.2	6.3	4
G032.379+0.102	47.3	3.2	11.2	N	B	6.1	3.2	5.6	8
G032.581-0.077	30.0	2.1	12.2	F	B	6.8	12.2	-16.4	4
G033.753-0.063	101.7	7.1	7.1	T	A	4.7	7.1	-7.8	2,4
G034.031-0.059	56.3	3.7	10.4	F	B	5.8	10.4	-10.7	1,4
G034.197-0.592	52.4	3.4	10.6	N	B	6.0	3.4	-35.5	6
G034.750+0.020	86.1	5.7	8.3	T	A	5.0	7.0	2.5	...
G036.909+0.491	-32.5	...	17.2	F	A	11.6	17.2	147.2	5
G037.027+0.123	82.2	5.7	7.8	T	A	5.2	6.8	14.6	1
G037.485+0.513	4.1	0.2	13.3	F	B	8.4	13.3	119.2	...
G038.120-0.227	83.8	6.7	6.7	N	B	5.2	6.7	-26.5	6

Table 6.3: HII Region Velocities and Distances

Source	V_{lsr}	D_N	D_F	KDAR	QF	R_{gal}	D	z	Reason ¹
	km s ⁻¹	kpc	kpc			kpc	kpc	pc	
G049.998-0.125	38.5	3.0	7.9	F	B	7.0	7.9	-17.3	6

¹Reasons – 1: Only one component from the source position spectrum was not detected in the off-target spectrum; 2: Only one component from the off-target position spectrum was 50% less intense than the corresponding source position component; 3: The line-to-continuum ratio for only one peak is within 1σ deviation of the mean; 4: The line-to-continuum ratio for all but one peak are outside 3σ deviation from the mean; 5: A single negative-velocity component was detected; 6: A molecular gas observation is within 10 km s⁻¹ of one of the components of this region; 7: A CO gas observation is within 10 km s⁻¹ of one of the components of this region; 8: A single positive-velocity component was detected; 9: Only one component from the off-target position spectrum was 50 mK less intense than the corresponding source position component.

6.2 Comments on Individual Sources

G019.594+0.024 - The source observations detect two velocity components at 35.3 km s^{-1} and 124.0 km s^{-1} . At the off-target position $(\ell, b) = (19.72^\circ, 0.18^\circ)$, we detect the source velocity component at 124.0 km s^{-1} with a similar intensity to that of the source observation. The source velocity component at 35.3 km s^{-1} that we do not detect at the off-target position is therefore the source velocity.

G021.933+0.103 - The source observations detect two velocity components at 40.6 km s^{-1} and 82.2 km s^{-1} . We observed three off-target positions at $(\ell, b) = (21.92^\circ, 0.06^\circ)$, $(\ell, b) = (21.89^\circ, 0.15^\circ)$, and $(\ell, b) = (21.99^\circ, 0.14^\circ)$. The off-target position $(\ell, b) = (21.92^\circ, 0.06^\circ)$ has no detection while the other two off-target positions have one velocity component detected near 60 km s^{-1} . Neither of the detected velocity components at these two diffuse positions were within 10 km s^{-1} of the two source velocity components. Molecular line analysis, however, supports 82.2 km s^{-1} as the source velocity.

G022.730−0.239 - The source observations detect two velocity components at 71.1 km s^{-1} and 113.7 km s^{-1} . We observed three off-target positions at $(\ell, b) = (22.70^\circ, -0.27^\circ)$, $(\ell, b) = (22.74^\circ, -0.19^\circ)$, and $(\ell, b) = (22.81^\circ, -0.20^\circ)$. At the off-target position $(\ell, b) = (22.70^\circ, -0.27^\circ)$, both source velocity components decreased in intensity by more than 50%. At the off-target position $(\ell, b) = (22.74^\circ, -0.19^\circ)$, the source velocity component at 71.1 km s^{-1} decreased in intensity by 50% and the source

velocity component at 113.7 km s^{-1} was not detected. At the off-target position $(\ell, b) = (22.81^\circ, -0.20^\circ)$, the source velocity component at 71.1 km s^{-1} decreased in intensity by $\sim 24 \text{ mK}$, a new component was detected at 95.1 km s^{-1} , and the source velocity component at 113.7 km s^{-1} had an intensity similar to that of the source observation. Assuming the velocity component detected at 95.1 km s^{-1} originates from diffuse gas, this supports 71.1 km s^{-1} as the source velocity.

G022.739–0.303 - The source observations detect two velocity components at 69.3 km s^{-1} and 112.1 km s^{-1} . We observed two off-target positions at $(\ell, b) = (22.78^\circ, -0.30^\circ)$ and $(\ell, b) = (22.70^\circ, -0.35^\circ)$. We detect both source velocity components at $(\ell, b) = (22.78^\circ, -0.30^\circ)$ with intensities similar to that of the source observation. At the off-target position $(\ell, b) = (22.70^\circ, -0.35^\circ)$, the source velocity component at 69.3 km s^{-1} decreased in intensity by $\sim 50\%$, while the source velocity component at 112.1 km s^{-1} was not detected. The latter component is likely the correct source velocity.

G022.755–0.246 - The source observations detect two velocity components at 70.2 km s^{-1} and 106.7 km s^{-1} . We observed three off-target positions at $(\ell, b) = (22.70^\circ, -0.27^\circ)$, $(\ell, b) = (22.74^\circ, -0.19^\circ)$, and $(\ell, b) = (22.81^\circ, -0.20^\circ)$. At the off-target position $(\ell, b) = (22.70^\circ, -0.27^\circ)$, we detect both source velocity components which decreased in intensity by more than 50%. At the off-target position $(\ell, b) = (22.74^\circ, -0.19^\circ)$, the source velocity component at 70.2 km s^{-1} decreased in intensity by 50% and

we do not detect the component at 106.7 km s^{-1} . At the off-target position $(\ell, b) = (22.81^\circ, -0.20^\circ)$, we detect a new velocity component at 95.1 km s^{-1} and the two source velocity components both decreased in intensity by more than 50%. Line-to-continuum analysis supports 70.2 km s^{-1} as the source velocity.

G022.986–0.149 - The correct source velocity was not determined. The source observations detect two velocity components at 76.6 km s^{-1} and 100.2 km s^{-1} . We observed three off-target positions at $(\ell, b) = (22.93^\circ, -0.15^\circ)$, $(\ell, b) = (23.00^\circ, -0.19^\circ)$, and $(\ell, b) = (23.04^\circ, -0.12^\circ)$. We detect both source velocity components at $(\ell, b) = (22.93^\circ, -0.15^\circ)$ with intensities of $\sim 50\%$ that of the source line intensities. We detect both source velocity components at $(\ell, b) = (23.00^\circ, -0.19^\circ)$ with line intensities comparable to that of the source line intensities. At the off-target position $(\ell, b) = (23.04^\circ, -0.12^\circ)$, we detect a broad component at 81.2 km s^{-1} that could not be associated with either of the source velocity components. The situation is therefore ambiguous.

G023.265–0.301 - The source observations detect two velocity components at 73.1 km s^{-1} and 97.1 km s^{-1} . We detect a broad velocity component at the off-target position $(\ell, b) = (23.22^\circ, -0.34^\circ)$ that is within 10 km s^{-1} of the 73.1 km s^{-1} velocity from the source position. We do not detect the source velocity component at 97.1 km s^{-1} . The situation is therefore slightly unclear, although since the 73.1 km s^{-1} velocity component decreased in intensity by $\sim 100 \text{ mK}$, it seems likely that this is

the source velocity.

G023.604−0.200 - The source observations detect two velocity components at 56.3 km s^{-1} and 82.7 km s^{-1} . At the off-target position $(\ell, b) = (23.59^\circ, -0.24^\circ)$, we detect velocity components at 55.5 km s^{-1} and 95.4 km s^{-1} . The higher velocity component of the off-target position is not within 10 km s^{-1} of the 82.7 km s^{-1} source velocity component but the line is $\sim 12 \text{ mK}$ weaker. Since the source velocity component at 56.3 km s^{-1} has similar intensity at the off-target position, the higher velocity is likely the correct source velocity.

G023.736−0.022 - The source observations detect three velocity components at 3.0 km s^{-1} , 58.1 km s^{-1} , and 100.6 km s^{-1} . We detect neither the 58.1 km s^{-1} nor the 3.0 km s^{-1} source velocity components at the diffuse position $(\ell, b) = (23.72^\circ, -0.05^\circ)$. Analysis of the line-to-continuum ratio supports 3 km s^{-1} being the source velocity. This is also supported by the fact that the original 3 km s^{-1} line intensity was $\sim 15 \text{ mK}$ while the 58.1 km s^{-1} component was $< 5 \text{ mK}$.

G023.836+0.104 - The source observations detect two velocity components at 41.9 km s^{-1} and 114.3 km s^{-1} . We do not detect the 41.9 km s^{-1} source velocity component at the off-target position $(\ell, b) = (23.85^\circ, -0.06^\circ)$ and the intensity of the source velocity component at 114.3 km s^{-1} was 50% less than that of the source position. The former source velocity component is likely the correct source velocity.

G024.500+0.487 - The source observations detect two velocity

components at 38.8 km s^{-1} and 98.9 km s^{-1} , with intensities of 11.1 mK and 149 mK, respectively. We observed two off-target positions at $(\ell, b) = (24.49^\circ, 0.43^\circ)$ and $(\ell, b) = (24.51^\circ, 0.54^\circ)$. The off-target position observation at $(\ell, b) = (24.49^\circ, 0.43^\circ)$ resulted in no detections. At the off-target position $(\ell, b) = (24.51^\circ, 0.54^\circ)$, we detect velocity components at 34.2 km s^{-1} and 100.5 km s^{-1} , both with intensities $< 10 \text{ mK}$. Because the 98.9 km s^{-1} line decreased in intensity by $> 100 \text{ mK}$, this is likely the source velocity.

G024.557–0.132 - The source observations detect two velocity components at 91.1 km s^{-1} and 111.6 km s^{-1} . At the off-target position $(\ell, b) = (24.52^\circ, -0.15^\circ)$, we detect two velocity components at 52.3 km s^{-1} and 92.3 km s^{-1} , but do not detect the source velocity component at 111.6 km s^{-1} . The line-to-continuum ratio and molecular line analysis suggest that the 91.1 km s^{-1} component is the source velocity.

G025.143–0.338 - The source observations detect three velocity components at 9.5 km s^{-1} , 59 km s^{-1} , and 118.2 km s^{-1} . We observed three diffuse positions at $(\ell, b) = (25.16^\circ, -0.37^\circ)$, $(\ell, b) = (25.18^\circ, -0.32^\circ)$, and $(\ell, b) = (25.11^\circ, -0.28^\circ)$. We do not detect the 9.5 km s^{-1} or 59.0 km s^{-1} components at any of these positions, and only detect the 118.2 km s^{-1} component at the off-target position $(\ell, b) = (25.16^\circ, -0.37^\circ)$. The line-to-continuum analysis supports 9.5 km s^{-1} as the source velocity.

G025.469–0.121 - The source observations detect two velocity components at 60.1 km s^{-1} and 96.9 km s^{-1} . We observed two off-target

positions at $(\ell, b) = (25.49^\circ, -0.17^\circ)$ and $(\ell, b) = (25.51^\circ, -0.07^\circ)$. At the off-target position $(\ell, b) = (25.49^\circ, -0.17^\circ)$, we detect the 60.1 km s^{-1} source velocity component, which decreased in intensity by 50%, and another velocity component at 110.8 km s^{-1} (more than 10 km s^{-1} from the source-position velocity 96.9 km s^{-1}). We detect two velocity components at the diffuse position $(\ell, b) = (25.51^\circ, -0.07^\circ)$, with velocities of 60.9 km s^{-1} and 107.3 km s^{-1} , and intensities of 13.8 mK and 10.9 mK, respectively. Because the 96.9 km s^{-1} component decreased in intensity by $> 50 \text{ mK}$, it seems likely that this is the source velocity, which is also supported by the line-to-continuum analysis.

G026.261+0.280 - The correct source velocity was not determined. The source observations detect two velocity components at 88.6 km s^{-1} and 117 km s^{-1} . We observed two off-target positions at $(\ell, b) = (26.29^\circ, 0.24^\circ)$ and $(\ell, b) = (26.23^\circ, 0.24^\circ)$. At the diffuse position $(\ell, b) = (26.29^\circ, 0.24^\circ)$ we detect velocity components at 95.0 km s^{-1} and 117.7 km s^{-1} , while at the diffuse position $(\ell, b) = (26.23^\circ, 0.24^\circ)$ we only detect one broad component at 108.0 km s^{-1} . The intensities for all these components are comparable to those of the source position, and therefore the situation is unclear.

G027.183−0.151 - The source observations detect two velocity components at 27.2 km s^{-1} and 95.5 km s^{-1} . At the off-target position $(\ell, b) = (27.22^\circ, -0.16^\circ)$, we detect a velocity component at 59.7 km s^{-1} , in addition to the two source velocities. The intensity of the source velocity component at 27.2 km s^{-1} , however, decreased by $> 50\%$, so this is likely

the source velocity.

G027.334+0.176 - The source observations detect three velocity components at 22.5 km s^{-1} , 80.4 km s^{-1} , and 102.5 km s^{-1} . At the off-target position $(\ell, b) = (27.33^\circ, 0.13^\circ)$, we do not detect the 22.5 km s^{-1} or the 80.4 km s^{-1} source velocity components. The line-to-continuum ratio supports 80.4 km s^{-1} as the source velocity.

G027.366−0.164 - The correct source velocity was not determined. The source observations detect two velocity components at 82.5 km s^{-1} and 102.5 km s^{-1} . At the off-target position $(\ell, b) = (27.37^\circ, -0.13^\circ)$ the detected velocity components cannot be definitively associated with the source velocity components. Therefore the situation is ambiguous.

G027.906−0.010 - The correct source velocity was not determined. The source observations detect two velocity components at 40.5 km s^{-1} and 96.4 km s^{-1} . At the off-target position $(\ell, b) = (27.95^\circ, 0.00^\circ)$, we detect both source-position components but their intensities decrease by $> 50\%$. The situation is ambiguous.

G028.291+0.012 - The source observations detect two velocity components at 44.4 km s^{-1} and 89.3 km s^{-1} . We observed two off-target positions at $(\ell, b) = (28.26^\circ, -0.03^\circ)$ and $(\ell, b) = (28.28^\circ, 0.06^\circ)$. At the off-target position $(\ell, b) = (28.26^\circ, -0.03^\circ)$, we detect the source velocity component at 44.4 km s^{-1} , and additional velocity components at 77.2 km s^{-1} and 103.1 km s^{-1} . At the off-target position $(\ell, b) = (28.28^\circ, 0.06^\circ)$, we detect the source velocity component at 89.3 km s^{-1} ,

but we do not detect the source velocity component at 44.4 km s^{-1} , so the source velocity is likely 44.4 km s^{-1} .

G028.394+0.076 - The source observations detect two velocity components at 42.8 km s^{-1} and 86.2 km s^{-1} . We observed two off-target positions at $(\ell, b) = (28.38^\circ, 0.04^\circ)$ and $(\ell, b) = (28.35^\circ, 0.08^\circ)$. At the off-target position $(\ell, b) = (28.38^\circ, 0.04^\circ)$, we detect both source velocity components at intensities similar to that of the source observation. At the off-target position $(\ell, b) = (28.35^\circ, 0.08^\circ)$, we do not detect the source velocity component at 42.8 km s^{-1} so the source velocity is likely 86.2 km s^{-1} .

G028.696+0.048 - The correct source velocity was not determined. The source observations detect three velocity components at 39.7 km s^{-1} , 100.7 km s^{-1} and 117 km s^{-1} . At the off-target position $(\ell, b) = (28.74^\circ, 0.07^\circ)$, we detect the first source velocity component with similar intensity while we detect the second component with an intensity $\sim 182 \text{ mK}$ less than that of the source-position observation. We do not detect the third source velocity component so the situation is ambiguous.

G029.433+0.273 - The source observations detect two velocity components at 33.4 km s^{-1} and 99 km s^{-1} . We observed two off-target positions at $(\ell, b) = (29.41^\circ, 0.24^\circ)$ and $(\ell, b) = (29.31^\circ, 0.30^\circ)$. At both off-target positions we detect both source velocity components with intensities similar to those of the source-position observation. The line-to-continuum ratio analysis supports 33.4 km s^{-1} as the source velocity.

G030.252+0.051 - The source observations detect two velocity components at 65.2 km s^{-1} and 101.7 km s^{-1} . At the off-target position $(\ell, b) = (30.29^\circ, 0.03^\circ)$ we do not detect the source velocity component at 65.2 km s^{-1} and the component at 101.7 km s^{-1} increased in intensity by $\sim 20 \text{ mK}$. This, line-to-continuum ratio analysis, and molecular line velocity support 65.2 km s^{-1} as the source velocity.

G030.345+0.092 - The source observations detect two velocity components at 42.9 km s^{-1} and 106.7 km s^{-1} . We observed two off-target positions at $(\ell, b) = (30.40^\circ, 0.06^\circ)$ and $(\ell, b) = (30.40^\circ, 0.14^\circ)$. At the off-target position $(\ell, b) = (30.40^\circ, 0.06^\circ)$ we do not detect the source velocity component at 42.9 km s^{-1} but we detect the 106.7 km s^{-1} component which decreased in intensity by $\sim 50\%$. At the off-target position $(\ell, b) = (30.40^\circ, 0.14^\circ)$ we do not detect the source velocity component at 42.9 km s^{-1} but we detect two new components at 67.4 km s^{-1} and 88.5 km s^{-1} . We detect the source velocity component at 106.7 km s^{-1} with an intensity that decreased by $\sim 12 \text{ mK}$, but this analysis left the situation unclear. The line-to-continuum ratio analysis supports 42.9 km s^{-1} as the source velocity.

G030.374+0.026 - The off-target position $(\ell, b) = (30.40^\circ, 0.06^\circ)$, that we observed for analysis of G30.378+0.106, was used for this analysis. The source observations detect two velocity components at 44.4 km s^{-1} and 101.1 km s^{-1} . We do not detect the source velocity component at 44.4 km s^{-1} at the aforementioned off-target position. We detect the

compoenent at 101.1 km s^{-1} with similar intensity to that of the source observation. This supports 44.4 km s^{-1} as the source velocity.

G30.378+0.106 - The source observations detect two velocity components at 66.1 km s^{-1} and 102 km s^{-1} . We observed two off-target positions at $(\ell, b) = (30.40^\circ, 0.06^\circ)$ and $(\ell, b) = (30.40^\circ, 0.14^\circ)$. At the off-target position $(\ell, b) = (30.40^\circ, 0.06^\circ)$, we do not detect the source velocity component at 66.1 km s^{-1} . We detect the 102 km s^{-1} component, which decreased in intensity by $\sim 50\%$. At the off-target position $(\ell, b) = (30.40^\circ, 0.14^\circ)$ we detect the source velocity component at 66.1 km s^{-1} with a similar intensity as that of the source-position observation. We also detect the 102 km s^{-1} component and an additional component at 88.5 km s^{-1} . This analysis left the situation unclear but line-to-continuum ratio and molecular line analysis supports 102 km s^{-1} as the source velocity.

G030.463−0.191 - The source observations detect two velocity components at 84.4 km s^{-1} and 107.5 km s^{-1} . At the off-target position $(\ell, b) = (30.44^\circ, -0.17^\circ)$, we detect the source velocity component at 84.4 km s^{-1} with a similar intensity as the source-position observation. We detect the source velocity component at 107.5 km s^{-1} , which decreased in intensity by almost 50%. This and line-to-continuum analysis support 107.5 km s^{-1} as the source velocity.

G030.597+0.030 - The source observations detect three velocity components at 44.9 km s^{-1} , 89.5 km s^{-1} , and 112.1 km s^{-1} . At the off-target position $(\ell, b) = (30.63^\circ, 0.01^\circ)$, we detect the source velocity

component at 44.9 km s^{-1} which decreased in intensity by $\sim 49 \text{ mK}$, a decrease of more than 50%. At this off-target position, we detect the source velocity components at 89.5 km s^{-1} and 112.1 km s^{-1} as one component at 102.3 km s^{-1} with similar intensity as that of the source-position observation. It is likely that 44.9 km s^{-1} is the correct source velocity.

G030.644+0.053 - The correct source velocity was not determined.

The source observations detect two velocity components at 39.3 km s^{-1} and 99.5 km s^{-1} . At the off-target position $(\ell, b) = (30.63^\circ, 0.01^\circ)$, we detect both source velocity components and both component's intensities decreased in intensity by more than 50%. The situation is ambiguous.

G030.696+0.256 - The source observations detect two velocity components at 38 km s^{-1} and 102.1 km s^{-1} . At the off-target position $(\ell, b) = (30.66^\circ, 0.32^\circ)$, we do not detect the source velocity component at 38 km s^{-1} ; we detect a new velocity component at 71.7 km s^{-1} , and detect the source velocity component at 102.1 km s^{-1} which decreased in intensity by $\sim 61 \text{ mK}$. This and line-to-continuum analysis support 102.1 km s^{-1} as the source velocity.

G030.760+0.206 - The source observations detect two velocity components at 38.3 km s^{-1} and 98.5 km s^{-1} . We observed three off-target positions at $(\ell, b) = (30.76^\circ, 0.17^\circ)$, $(\ell, b) = (30.78^\circ, 0.25^\circ)$, and $(\ell, b) = (30.72^\circ, 0.23^\circ)$. At the off-target positions $(\ell, b) = (30.76^\circ, 0.17^\circ)$ and $(\ell, b) = (30.72^\circ, 0.23^\circ)$ we detect the source velocity component at 38.3 km s^{-1} with an intensity similar to that of the source-position

observation. The 38.3 km s^{-1} component we detect at $(\ell, b) = (30.78^\circ, 0.25^\circ)$ has a higher intensity than the source observation. We detect the 98.5 km s^{-1} source velocity component and an additional velocity component at $\sim 113 \text{ km s}^{-1}$, at the off-target positions $(\ell, b) = (30.76^\circ, 0.17^\circ)$ and $(\ell, b) = (30.72^\circ, 0.23^\circ)$. At $(\ell, b) = (30.72^\circ, 0.23^\circ)$, the intensity of the 98.5 km s^{-1} source velocity component is almost identical to that of the source observation. The situation is complicated and unclear, but line-to-continuum and molecular line analysis supports 98.5 km s^{-1} as the source velocity.

G030.771−0.223 - The correct source velocity was not determined. The source observations detect two velocity components at 46.8 km s^{-1} and 103.6 km s^{-1} . We observed two off-target positions at $(\ell, b) = (30.72^\circ, -0.21^\circ)$ and $(\ell, b) = (30.82^\circ, -0.28^\circ)$. At the off-target position $(\ell, b) = (30.72^\circ, -0.21^\circ)$, we do not detect the source velocity component at 46.8 km s^{-1} . We detect the source velocity component at 103.6 km s^{-1} with an intensity that decreased more than 50%. At the diffuse position $(\ell, b) = (30.82^\circ, -0.28^\circ)$, we detect both source velocity components and their intensities decreased by more than 50%; the situation remains unclear.

G030.797+0.165 - The off-target position $(\ell, b) = (30.76^\circ, 0.17^\circ)$, that we observed for analysis of G030.760+0.206, was used for this analysis. The source observations detect three velocity components at 40.4 km s^{-1} , 86 km s^{-1} , and 106.1 km s^{-1} . At the off-target position, we detect the three source velocity component. The component at 40.4 km s^{-1} decreased in

intensity by ~ 65 mK, a decrease of more than 50%, while the intensities of the the other two components were similar to that of the source observation. The source velocity 40.4 km s^{-1} is likely the source velocity.

G030.852+0.149 - The off-target position $(\ell, b) = (30.76^\circ, 0.17^\circ)$, that we observed for analysis of G030.760+0.206, was used for this analysis. The source observations detect three velocity components at 39.6 km s^{-1} , 88.7 km s^{-1} , and 114.5 km s^{-1} . At the off-target position, we detect the three source velocity component. The component at 39.6 km s^{-1} decreased in intensity by ~ 181 mK, a decrease of more than 50%, while the intensities of the the other two components were similar to that of the source observation. The source velocity 39.6 km s^{-1} is likely the source velocity.

G030.838+0.114 - The correct source velocity was not determined. The diffuse position $(\ell, b) = (30.76^\circ, 0.17^\circ)$, that we observed for analysis of G030.760+0.206, was used for this analysis. The source observations detect two velocity components at 35.8 km s^{-1} and 104.1 km s^{-1} . At the off-target position, we detect the both source velocity component with intensities that decrease by more than 50%, so the situation is ambiguous.

G030.907+0.016 - The off-target position $(\ell, b) = (30.92^\circ, 0.05^\circ)$, that we observed for analysis of G030.883+0.071, was used for this analysis. The source observations detect two velocity components at 38.8 km s^{-1} , and 96.3 km s^{-1} . We detect the source velocity component at 38.8 km s^{-1} , which increased in intensity by ~ 8 mK, and the source velocity component at 96.3 km s^{-1} , which decreased in intensity by ~ 30 mK, a decrease that is

not more than 50%. Line-to-continuum analysis support 96.3 km s^{-1} as the source velocity.

G031.104+0.125 - The correct source velocity was not determined. The source observations detect three velocity components at 40 km s^{-1} , 85 km s^{-1} and 105.3 km s^{-1} . We observed three off-target positions at $(\ell, b) = (31.13^\circ, 0.08^\circ)$, $(\ell, b) = (31.08^\circ, 0.17^\circ)$, and $(\ell, b) = (31.13^\circ, 0.17^\circ)$. At $(\ell, b) = (31.13^\circ, 0.08^\circ)$ and $(\ell, b) = (31.08^\circ, 0.17^\circ)$, we detect all three source velocity components at similar intensities to those of the source observation. At $(\ell, b) = (31.13^\circ, 0.17^\circ)$, we detect all three source velocity components at $\sim 50\%$ the intensity of the source observation. The situation is ambiguous.

G031.140+0.121 - The same off-target positions we observed for G031.104+0.125 were used for this analysis. The source observations detect three velocity components at 45.5 km s^{-1} , 81.6 km s^{-1} and 102.9 km s^{-1} . This determination experienced the same difficulties mentioned for G031.104+0.125 but line-to-continuum analysis supports 45.5 km s^{-1} as the source velocity.

G031.157−0.148 - The source observations detect two velocity components at 43.6 km s^{-1} and 101.6 km s^{-1} . We observed two off-target positions at $(\ell, b) = (31.11^\circ, -0.15^\circ)$ and $(\ell, b) = (31.17^\circ, -0.18^\circ)$. At the off-target position $(\ell, b) = (31.11^\circ, -0.15^\circ)$, we detect a velocity component at 20.1 km s^{-1} , the source velocity component at 43.6 km s^{-1} (with an intensity similar to that of the source observation), and the source

velocity component at 101.6 km s^{-1} (which decreased in intensity by $\sim 50\%$). At the off-target position $(\ell, b) = (31.17^\circ, -0.18^\circ)$, we detect the source velocity component at 43.6 km s^{-1} (which decreased in intensity by $\sim 67 \text{ mK}$) and the source velocity component at $101. \text{ km s}^{-1}$ (with an intensity similar to that of the source observation). Molecular line analysis supports 43.6 km s^{-1} as the source velocity.

G031.159+0.048 - The same off-target positions we observed for G031.104+0.125 were used for this analysis. The source observations detect two velocity components at 35.6 km s^{-1} and 100.7 km s^{-1} . This determination experienced the same difficulties mentioned for G031.104+0.125 but line-to-continuum analysis supports 35.6 km s^{-1} as the source velocity.

G031.207+0.098 - The correct source velocity was not determined. The source observations detect two velocity components at 45.5 km s^{-1} and 102.6 km s^{-1} . We observed four off-target positions at $(\ell, b) = (31.17^\circ, 0.10^\circ)$, $(\ell, b) = (31.21^\circ, 0.06^\circ)$, $(\ell, b) = (31.24^\circ, 0.12^\circ)$, and $(\ell, b) = (31.20^\circ, 0.13^\circ)$. At off-target positions $(\ell, b) = (31.17^\circ, 0.10^\circ)$ and $(\ell, b) = (31.21^\circ, 0.06^\circ)$, we detect both source velocity components with similar intensities to that of the source observation. At the off-target position $(\ell, b) = (31.24^\circ, 0.12^\circ)$, we detect no emission. At the off-target position $(\ell, b) = (31.20^\circ, 0.13^\circ)$, we detect the source velocity component at 45.5 km s^{-1} , with a similar intensity to that of the source observation, and the source velocity component at 102.6 km s^{-1} , with approximately the same intensity.

There is not enough evidence to make a clear determination.

G032.108+0.050 - The source observations detect two velocity components at 45.2 km s^{-1} and 94.4 km s^{-1} . We observed two off-target positions at $(\ell, b) = (49.94^\circ, -0.13^\circ)$ and $(\ell, b) = (50.06^\circ, -0.14^\circ)$. At the off-target position $(\ell, b) = (49.94^\circ, -0.13^\circ)$, we detect both of the source velocity components, both of which decrease in intensity by more than 50%. At the diffuse position $(\ell, b) = (50.06^\circ, -0.14^\circ)$, we detect the source velocity component at 45.2 km s^{-1} , with an intensity similar to that of the source position, and the source velocity component at 94.4 km s^{-1} , which decreased in intensity by 50%. This indicates that 94.4 km s^{-1} is likely the source velocity.

G033.994−0.006 - The correct source velocity was not determined. The source observations detect two velocity components at 38.3 km s^{-1} and 55.8 km s^{-1} . At the off-target position $(\ell, b) = (33.97^\circ, 0.03^\circ)$, we detect both source velocity components, both of which decreased in intensity by more than 50%.

G034.197−0.592 - The source observations detect two velocity components at 52.4 km s^{-1} and 72.8 km s^{-1} . At the off-target position $(\ell, b) = (34.26^\circ, -0.61^\circ)$ we do not detect any emission. Molecular line analysis supports 52.4 km s^{-1} as the source velocity.

G035.260+0.122 - The correct source velocity was not determined. The source observations detect three velocity components at 38.1 km s^{-1} , 68.6 km s^{-1} and 92 km s^{-1} . We observed two off-target positions at $(\ell, b) =$

$(35.31^\circ, 0.10^\circ)$ and $(\ell, b) = (35.22^\circ, 0.10^\circ)$. At the off-target position $(\ell, b) = (35.31^\circ, 0.10^\circ)$, we only detect the source velocity component at 38.1 km s^{-1} with similar intensity to that of the source observation. At the diffuse position $(\ell, b) = (35.22^\circ, 0.10^\circ)$ we detect a velocity component at 56.2 km s^{-1} , but cannot associated with any of the source velocity components. The situation is ambiguous.

G037.432−0.337 - The correct source velocity was not determined. The source observations detect two velocity components at 44.1 km s^{-1} and 73.7 km s^{-1} . We observed two off-target positions at $(\ell, b) = (37.37^\circ, -0.35^\circ)$ and $(\ell, b) = (37.46^\circ, -0.41^\circ)$. At both off-target positions, we detect the source velocity component 44.1 km s^{-1} , which decrease in intensity by 50%, but not the source velocity component at 73.7 km s^{-1} . The situation is ambiguous.

G037.485+0.513 - The correct source velocity was not determined. The source observations detect three velocity components at 4.1 km s^{-1} , 50 km s^{-1} and 90.8 km s^{-1} . At the off-target position $(\ell, b) = (37.55^\circ, 0.54^\circ)$, we do not detect the source velocity components at 4.1 km s^{-1} and 90.8 km s^{-1} . We detect the component at 50 km s^{-1} with a similar intensity to that of the source observation, but the situation is ambiguous.

G038.120−0.227 - The source observations detect two velocity components at 54.7 km s^{-1} and 83.8 km s^{-1} . At the off-target position $(\ell, b) = (38.11^\circ, -0.20^\circ)$, we detect the source velocity component at 54.7 km s^{-1}

with an intensity similar to that of the source velocity, do not detect the source velocity component at 83.8 km s^{-1} , but we do detect a velocity component at 71.9 km s^{-1} with an intensity of $\sim 8 \text{ mK}$. The diffuse observations leave the situation ambiguous but molecular line analysis supports 83.8 km s^{-1} as the source velocity.

G049.998–0.125 - The source observations detect two velocity components at 38.5 km s^{-1} and 73.2 km s^{-1} . We observed two off-target positions at $(\ell, b) = (49.94^\circ, -0.13^\circ)$ and $(\ell, b) = (50.06^\circ, -0.14^\circ)$. At the off-target position $(\ell, b) = (49.94^\circ, -0.13^\circ)$, we do not detect either of the source velocity components. At the off-target position $(\ell, b) = (50.06^\circ, -0.14^\circ)$, we do not detect the source velocity component at 38.5 km s^{-1} , but do detect the component at 73.2 km s^{-1} which decreased in intensity by just over 50%. This and molecular line analysis supports 38.5 km s^{-1} as the source velocity.

G023.909+0.066 - The source observations detect two velocity components at 38.4 km s^{-1} and 107.9 km s^{-1} . At the off-target position $(\ell, b) = (23.86^\circ, 0.04^\circ)$ we do not detect the source velocity component at 38.4 km s^{-1} , but do detect the source velocity component at 107.9 km s^{-1} . The 107.9 km s^{-1} component, however, was resolved into two separate velocity components of lower intensity, both within 10 km s^{-1} of the 107.9 km s^{-1} velocity. This and CO observations support 38.4 km s^{-1} as the source velocity.

G024.400–0.190 - The source observations detect two velocity

components at 54.7 km s^{-1} and 101.0 km s^{-1} . We observed two off-target positions at $(\ell, b) = (24.43^\circ, -0.18^\circ)$ and $(\ell, b) = (24.37^\circ, -0.23^\circ)$. At the off-target position $(\ell, b) = (24.43^\circ, -0.18^\circ)$, we detect both source velocity components but neither of their intensities decreased by more than 50%. At the diffuse position $(\ell, b) = (24.37^\circ, -0.23^\circ)$, we detect both source velocity components, but only the component at 101.0 km s^{-1} decreased in intensity by 50%. The analysis of Anderson et al. (2009), however, supports 54.7 km s^{-1} as the source velocity.

G024.507−0.222 - The source observations detect two velocity components at 42.2 km s^{-1} and 96.3 km s^{-1} . We observed two off-target positions at $(\ell, b) = (24.50^\circ, -0.18^\circ)$ and $(\ell, b) = (24.48^\circ, -0.20^\circ)$. At the off-target position $(\ell, b) = (24.50^\circ, -0.18^\circ)$, we detect the source velocity components at 42.2 km s^{-1} , 96.3 km s^{-1} , and an additional velocity component at 123.8 km s^{-1} . At the off-target position $(\ell, b) = (30.42^\circ, -0.03^\circ)$, we detect the source velocity component at 96.3 km s^{-1} and an additional velocity component at 52.9 km s^{-1} . Regardless, at both off-target positions, the intensity of source velocity component at 96.3 km s^{-1} decreased by $\sim 200 \text{ mK}$, so this is likely the source velocity.

G024.909+0.432 - The source observations detect two velocity components at 108.6 km s^{-1} and 135.1 km s^{-1} . At the off-target position $(\ell, b) = (24.96^\circ, 0.39^\circ)$, we detect the source velocity component at 108.6 km s^{-1} , which decreased in intensity by more than 50%, and do not detect the component at 135.1 km s^{-1} . The source velocity component at

135.1 km s⁻¹ is likely source velocity.

G025.700+0.030 - The source observations detect three velocity components at 52.7 km s⁻¹, 83.4 km s⁻¹, and 124.2 km s⁻¹. At the off-target position $(\ell, b) = (25.66^\circ, 0.07^\circ)$, we detect all three source velocity components with less than 50% of the intensity of the source observation. Since the source velocity component at 52.7 km s⁻¹ decreased in intensity by ~ 190 mK, it is likely the source velocity.

G028.609+0.021 - The correct source velocity was not determined. The source observations detect two velocity components at 40.3 km s⁻¹ and 96.6 km s⁻¹. At the off-target position $(\ell, b) = (28.64^\circ, -0.04^\circ)$, we do not detect the source velocity component at 40.3 km s⁻¹. We detect the component at 96.6 km s⁻¹ which decreased in intensity by ~ 160 mK. The situation is ambiguous.

G030.470-0.040 - The source observations detect two velocity components at 42.7 km s⁻¹ and 101.4 km s⁻¹. We observed two off-target positions at $(\ell, b) = (30.53^\circ, -0.03^\circ)$ and $(\ell, b) = (30.42^\circ, -0.04^\circ)$. At the off-target position $(\ell, b) = (30.53^\circ, -0.03^\circ)$, we detect the source velocity component at 101.4 km s⁻¹ which was resolved into two separate componets, both within 10 km s⁻¹ of the source velocity component and of similar intensity to that of the source observation. We also detect an additional velocity component at 57.6 km s⁻¹. At the off-target position $(\ell, b) = (30.42^\circ, -0.03^\circ)$, we detect the source velocity component at 101.4 km s⁻¹ which was resolved into two separate componets, both within

10 km s^{-1} of the source velocity component and of similar intensity to that of the source observation. Since we did not detect the component at 42.7 km s^{-1} , this is likely the source velocity.

G030.698−0.628 - The correct source velocity was not determined.

The source observations detect two velocity components at 87.8 km s^{-1} and 110.2 km s^{-1} . At the off-target position $(\ell, b) = (30.73^\circ, -0.61^\circ)$, we detect a broad component that, if fitted with one Gaussian, had a velocity between the velocities of the source velocity components. Two Gaussians could not be adequately fit to the spectrum, so the situation is ambiguous.

G031.054+0.088 - The source observations detect two velocity components at 20.1 km s^{-1} and 97.8 km s^{-1} . At the off-target position $(\ell, b) = (31.02^\circ, 0.12^\circ)$, we do not detect a component within 10 km s^{-1} of the 20.1 km s^{-1} source velocity component. We detect a velocity component at 38.6 km s^{-1} and the source velocity component at 97.8 km s^{-1} was resolved into two separate velocity components with similar intensity to that of the source observation. This and CO observations support the source velocity being 20.1 km s^{-1} .

G031.070+0.050 -The source observations detect two velocity components at 35.4 km s^{-1} and 98.6 km s^{-1} . We observed two off-target positions at $(\ell, b) = (31.09^\circ, 0.00^\circ)$ and $(\ell, b) = (31.11^\circ, 0.06^\circ)$. At the off-target position $(\ell, b) = (31.09^\circ, 0.00^\circ)$, we detect the source velocity component at 35.4 km s^{-1} (which decreased in intensity by more than 50%), the source velocity component at 98.6 km s^{-1} at an intensity similar

to that of the source observation, and an additional component at 114.2 km s^{-1} . At the off-target position $(\ell, b) = (31.11^\circ, 0.06^\circ)$, we detect the source velocity component at 35.4 km s^{-1} (which decreased in intensity by more than 50%), the source velocity component at 98.6 km s^{-1} at an intensity similar to that of the source observation, and an additional component at 84.1 km s^{-1} . The source velocity is likely 35.4 km s^{-1} .

G031.240−0.110 - The source observations detect two velocity components at 26.5 km s^{-1} and 90.3 km s^{-1} . We observed two off-target positions at $(\ell, b) = (31.23^\circ, -0.06^\circ)$ and $(\ell, b) = (31.23^\circ, -0.07^\circ)$. At both off-target positions, we detect the source velocity component at 26.5 km s^{-1} (which decreased in intensity by more than 50%), the source velocity component at 90.3 km s^{-1} at an intensity similar to that of the source observation, and an additional component at $\sim 78 \text{ km s}^{-1}$. This and CO observations support the source velocity being 26.5 km s^{-1} .

G031.607+0.334 - The source observations detect two velocity components at 24.4 km s^{-1} and 96.4 km s^{-1} . At the off-target position $(\ell, b) = (31.57^\circ, 0.27^\circ)$, we detect the source velocity component at 96.4 km s^{-1} at similar intensity to that of the source observation and an additional component 116.1 km s^{-1} . We do not detect the source velocity component at 24.4 km s^{-1} so this is likely the source velocity.

G031.816−0.121 -The source observations detect two velocity components at 36.3 km s^{-1} and 104.3 km s^{-1} . At the off-target position $(\ell, b) = (31.76^\circ, -0.11^\circ)$ we detect the source velocity component at

36.3 km s⁻¹, which decreased in intensity by more than 50%. We detect the source velocity component at 104.3 km s⁻¹ which is resolved into two separate velocity components, both of which are within 10 km s⁻¹ of the 104.3 km s⁻¹ source velocity component. The source velocity is likely 36.3 km s⁻¹.

G034.750+0.020 - The correct source velocity was not determined. The source observations detect two velocity components at 52.0 km s⁻¹ and 86.1 km s⁻¹. We observed three off-target positions at $(\ell, b) = (34.76^\circ, 0.07^\circ)$, $(\ell, b) = (34.82^\circ, 0.02^\circ)$, and $(\ell, b) = (34.75^\circ, -0.04^\circ)$. At the off-target position $(34.76^\circ, 0.07^\circ)$, we detect the source velocity components; neither decreased in intensity by 50%. At the diffuse position $(\ell, b) = (34.82^\circ, 0.02^\circ)$, we again detect both source velocity components, and both decrease in intensity by $> 50\%$. At the off-target position $(\ell, b) = (34.75^\circ, -0.04^\circ)$, we detect the source velocity component at 52.0 km s⁻¹ which decreased in intensity by 50%; we do not detect the source velocity component at 86.1 km s⁻¹.

Bibliography

- Anderson, L. D., Bania, T. M., Balser, D. S., & Rood, R. T. 2011, *ApJS*, 194, 32
- . 2012, *ApJ*, 754, 62
- Anderson, L. D., Bania, T. M., Jackson, J. M., Clemens, D. P., Heyer, M., Simon, R., Shah, R. Y., & Rathborne, J. M. 2009, *ApJS*, 181, 255
- Balser, D. S. 2006, *AJ*, 132, 2326
- Heiles, C., Reach, W. T., & Koo, B.-C. 1996, *ApJ*, 466, 191
- Jackson, J. M., et al. 2006, *ApJS*, 163, 145
- Lilley, A. E., & Palmer, P. 1968, *ApJS*, 16, 143
- Lockman, F. J. 1989, *ApJS*, 71, 469
- Lockman, F. J., Pisano, D. J., & Howard, G. J. 1996, *ApJ*, 472, 173
- Martins, F., Pomarès, M., Deharveng, L., Zavagno, A., & Bouret, J. C. 2010, *A&A*, 510, A32+
- Quireza, C., Rood, R. T., Balser, D. S., & Bania, T. M. 2006, *ApJS*, 165, 338
- Roman-Duval, J., Jackson, J. M., Heyer, M., Johnson, A., Rathborne, J., Shah, R., & Simon, R. 2009, *ArXiv e-prints*
- Sewilo, M., Churchwell, E., Kurtz, S., Goss, W. M., & Hofner, P. 2004, *ApJ*, 605, 285